Phyſico-Mechanical LECTURES.

OR, AN

ACCOUNT

OF WHAT IS

Explain'd and Demonſtrated

IN THE

COURSE

OF

Mechanical *and* Experimental

PHILOSOPHY,

GIVEN BY

J. T. Deſaguliers, M. A. F. R. S.

Wherein the Principles of *Mechanics*, *Hydroſtatics* and *Optics*, are demonſtrated and explain'd by a great Number of Experiments. Deſign'd for the Uſe of all ſuch as have ſeen, or may ſee Courſes of Experimental Philoſophy.

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TO THE

READER.

THE following Papers being only Minutes of my Lectures, for the Use of ſuch Gentlemen as have been my Auditors, were printed at their Deſire; to ſave the trouble of Writing them over for every Perſon. Therefore I beg all ſuch Readers, as have not ſeen my Courſe of Experiments, to pardon my want of Method and ſhort Hints; and deſire them not to expect a full Account of all the Experiments made in the Courſe, and mention'd in the Catalogues: For I have only taken Notice of ſo many as prove every Propoſition; that this little Book may ſerve as a *Memorandum.*

When I have more leiſure, I ſhall publiſh the Lectures in full, in a large Volume, with above 60 Copper Plates; wherein I ſhall endeavour to make my ſelf underſtood, to ſuch as are altogether unskill'd in Mathematics; but at the ſame time by Marginal Notes refer to the Authors, where each Truth that I ſhall lay down is mathematically demonſtrated.

ERRATA.

PAge 2. Line 23. read *Mercury, when little.* p. 6. l. 4. r. *Tubes.* p. 10. l. 25. r. *Powder too great for the Earth's Attraction, to bring it down nearer to the Earth, it would.* p. 11. l. 2. r. *that drew it.* p. 12. l. 4. r. *one Inch in a second of Time*) last l. dele *in a second of Time.* p. 16. l. 11. r. *falsly imagine,* l. 15. r. *inclin'd Planes.* p. 20. l. *penult.* r. *the Blow, A and B will.* p. 22. l. 16. r. *which bears.* p. 26. l. 13. r. *least of its Weight,* l. 26. r. *loss of,* l. 29. r. *at the top,* l. ibid. dele , *after Water.* p. 27. l. 1. r. *Equal Bodies,* l. 20. r. *encreas'd, in Proportion as the Surface, on,* l. 23. r. *not narrower than,* l. *ult.* r. *an Hole on the said Plane.* p. 31. l. 13. r. *no higher.* p. 32. l. 7. r. *Lungs and the,* l. 20. r. *communicates with.* p. 33. l. *penult.* r. *the Square Feet contain'd.* p. 36. l. 3. r. *the Barometer; fill.* p. 37. l. 11. r. *fall with a Vibrating Motion.* p. 40. l. 19. r. *in the Wind-Gun.* p. 41. l. 2. r. *Hemispheres.* p. 46. l. *antepenult.* r. *the Sine of the Angle of.* p. 47. l. 1. dele *a,* l. 5. dele *When the,* &c. *quite to the End of that Paragraph.* p. 49. l. 28. r. *such Rays therefore.* p. 54. l. 29. r. *diverging from each Point, will.* p. 59. l. 12. r. *so great as.* p. 63. l. 7. r. *whereby an.* p. 71. l. 6. r. *which is most.*

A COURSE OF *Experimental Philosophy.*

MECHANICS.

LECTURE I.

1. MATTER is what has Extension and Resistance; which are Properties of all kinds of Bodies.

2. Besides these, *Gravity* is an universal Principle in Matter; that is, all Bodies tend to one another, according to the Quantity of solid Matter in each Body. As for Example: The Sun attracts the Earth, and the Earth the Sun; the Earth the Moon, the Moon the Earth: And in short, all heavenly Bodies have a *Gravitation* or

Attraction towards one another; as is fully Demonstrated by Sir *Isaac Newton*.

3. By the Experiment of the Light of the Candle passing thro' a Hole in the Paper, was shewn the Law of that Gravity, or general Attraction; which decreases as you recede from the Center of the attracting Body, just as the Square of the Distances encreases. As for Example: If we were twice as far remov'd from the Sun as we are, we should be attracted by it four times more weakly; if 3 times as far, the Attraction would be 9 times less.

Note, *That* Light, Heat, *and all* Qualities *propagated from a* Center, *every way observe the same Laws.*

4. There is another kind of *Attraction*, namely, that of *Cohœsion*; which is called the *Electrical Attraction unexcited*; which is very strong when the Parts of Bodies touch one another, but decreases (when the Parts of Bodies are at any sensible Distance) much faster than Gravity, so as to become almost insensible then. This Attraction is prov'd by the Experiments made on the Drop of Oil of Oranges; on the Mercury, in the Case where little Cylinders of Glass and Iron lye at the bottom of it; on the red Water and Blood rising in small Tubes, the Hyperbola of ting'd Water rising between the two Glass Planes, and the Mercury rising in a clean'd Brass Tube with a concave Surface.

5. The *repelling Force* in Bodies, and the *Electrical Attraction excited*, appears from the Experiments made with the large Glass Tube rubb'd with the Hand, which first attracts, and then repells several (or indeed all) Bodies; as appear'd in the Experiments made upon Cork, Lead, Glass, Iron, Feathers, Leaf-Gold, *&c*. N. B. *A Feather, or any other light Body, when once attracted by the*

rubb'd

rubb'd Tube, ſo as to touch it, will always be repell'd from it, till it has touch'd ſome other Body.

6. Bodies are compounded of ſeveral Combinations of the firſt ſolid Particles of Matter; thoſe Bodies that have moſt Compoſitions, having leaſt Matter, or moſt Vacuity. Each Compoſition affording new Pores, larger than thoſe of the laſt Compoſition before.

LECTURE II.

1. MOTION is that Force by which a Body continually changes its place: the Quantity of it is known by multiplying the Quantity of Matter into the Velocity; ſo that a little Body may have as much Motion as a great one, if it has as much more Velocity as it has leſs Matter. The Thing was prov'd by a Spring ſhooting forwards two unequal Leads with the ſame Force.

2. A Down Feather and a Guinea, fall equally faſt in a Glaſs from which the Air is drawn; from this, and the former Experiment may be deduc'd, that Gravity towards the Earth (or the Force by which Bodies fall) is always equal to the Quantity of Matter in Bodies: Whence it follows, That if two equal Bodies (as the Cube of Iron, and that of Wood) weigh unequally, there muſt be Vacuities interſpers'd in that which weighs leaſt.

3. Another Proof of a *Vacuum* is thus deduc'd from the laſt Experiment. Mercury weighs 14 times more than Water; and accordingly it reſiſts to a Body moving in it, 14 times more than Water.

ter. Water weighs and resists 850 times more than Air; whence it follows, that the Resistance of a Medium, is proportionable to its Quantity of Matter. Therefore, as the Feather falling in the exhausted Receiver, meets with no sensible Resistance,, as it does when it falls in the Air, there must be no sensible Quantity of Matter in the said Receiver; and consequently a Vacuity must be interspers'd all over it. If all the World was full of Matter, tho' ne'er so subtile, Bodies moving in such a Fluid, would be more resisted than if they mov'd in Quick-Silver.

4. The *Materia subtilis* (according to the *Cartesians*) impells heavy Bodies downwards, therefore it must have Resistance; but it makes no Resistance in the exhausted Receiver, therefore it is not there. If there was any Matter without Resistance, it would no longer be Matter: Its being divided into fine Parts not taking away the Resistance; for a Pound of Gold weighs as much when in Dust, as in a solid Lump.

5. Light has a Velocity 100000 times greater than a Cannon-Ball; if therefore a Duck-Shot had the Velocity of Light, it would strike any thing as strongly as a Cannon-Ball 100000 times bigger, moving with all the Swiftness that it receives from the Powder. N. B. *Light comes from the Sun in about eight Minutes, and from the fixed Stars, in about Six Months; whereas a Cannon-Ball would be* 25 *Years in going the first, and* 50000 *Years in going the last Journey.*

6. The whole Effect of *mechanical Engines*, to sustain great Weights with a small Power, is produc'd by diminishing the Velocity of the Weight to be rais'd, and increasing that of the Power in a reciprocal Proportion, of the two Weights, and their Velocities; that is, by giving as much more Velocity

Velocity to the Power, as it weighs leſs (or has leſs Matter) than the Weight; that the Quantity of Matter fix'd at each end of a Machine (for Example of a Steel-Yard) being multiplied by its Velocity, may ſhew that there is an equal Quantity of Motion at each end; but equal Motions acting with contrary Directions, deſtroy one another, and ſo cauſe an Æquilibrium. If you give the Power a little more than the above-mention'd Velocity, it will over-poiſe, or raiſe the Weight.

7. Three *Centers*; that of $\left\{\begin{array}{l}\textit{Magnitude}\\ \textit{Motion}\\ \textit{Gravity}\end{array}\right\}$ in Bodies.

8. The Center of *Magnitude* is the Middle.

9. The Center of *Motion*, is a fix'd Point, round which a Body turns, or endeavours to turn.

10. The Center of *Gravity*, is that Point by which if a Body is ſuſpended, it will remain in any given Poſition.

11. If the Center of Gravity be not in the Center of Motion, it will deſcend till it goes under the Center of Motion, unleſs it be perpendicularly over it. This Truth gives us a Method for finding the Center of Gravity of the moſt irregular Bodies, by ſuſpending them ſucceſſively by different Sides, and marking where a Plumb-Line let fall from the Center of Suſpenſion, touches the Body in each Caſe; obſerve where thoſe Lines interſect, and at that Interſection the Center of Gravity will be.

12. The Center of Gravity is in the middle of a regular and homogeneous Body; but not in the Center of Bodies that are not ſo; as appears from the Experiments of the round Piece of Wood with Lead on one ſide, and of the Tobacco-Pipe broken at its Center of Gravity, and then weigh'd.

13. Bodies inclin'd, cannot fall, if their Line of Directions falls within their Baſes, otherwiſe they

they muſt fall. It is upon that Principle that we keep ourſelves from falling, as we walk. That the double Conic ſolid, ſeems to riſe of it ſelf upon the Glaſs Tube, tho' it really deſcends: And that a Stick, which of it ſelf would fall from the Table, is kept from falling, by hanging a Pail of Water to it; becauſe the Center of Gravity of the Stick, which cou'd deſcend at firſt, alters its place, and cannot deſcend when the Pail is hung on; no Body being able to deſcend, unleſs its Center of Gravity can fall.

LECTURE III.

1. THE *Reciprocal Proportion* between two counter-ballancing Weights, and their Velocities holds good in all the mechanical Powers.

Theſe Powers are Six. 1. *The Balance.* 2. *The Leaver.* 3. *The Pulley.* 4. *The Axis in Peritrochio.* 5. *The Wedge.* And 6. *The Screw.* Tho' the Screw being only a Wedge carried round a Cylinder, a great many count but Five mechanical Powers.

1. A Balance has either equal *Brachia* (as in the common Scales) or unequal ones, as in the *Statera Romana.* To have the Balance Horizontal, when in Æquilibrio, the Center of Motion muſt be a little above that of Gravity. The falſe Balance is a common pair of Scales, whoſe Beam is unequally divided, tho' it is not eaſily perceiv'd: But changing the Scales diſcovers the Cheat.

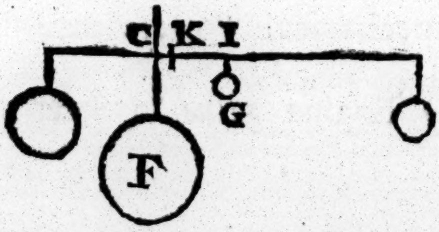
To

To find the Center of Gravity of two Weights apply'd to a Balance of known length, take this Analogy.

As the Sum of the Weights :
To the least Weight : :
So the Length of the Balance :
To the distance of the great Weight from the Center of Gravity.

This Analogy not giving the Place of the Center of Gravity exactly for Practise, by reason of the Weight of the Beam of the Balance, hang a Weight F equal to the two others, at their common Center of Gravity, and a Weight G equal to the Beam of the Balance, at the Center of Gravity of the Balance, and say,

As the Sum of the Weights F *and* G :
To the lesser Weight G : :
So the Distance C I *of these two new Weights.*
To the Distance of the Weight F, *from the true Center of Gravity* K.



2. There are four Sorts of Leavers. The Leaver of the 1*st* kind, has the Weight at one end, and the Power at the other, with the Center of Motion between. The Leaver of the 2*d* kind, has the Center of Motion at one end, and the Power at the other, with the Weight between. The Leaver of the 3*d* kind, has the Center of Motion at one end, and the Weight at the other, with the Power between.

The

The Leaver of the *4th* kind, is only a bended Leaver of the firſt kind.

A compound Leaver is more uſeful than a ſimple One of the ſame Length.

3. An upper Pulley adds nothing to the Power, but a lower One doubles its Force. In compound Pullies, the above-mention'd reciprocal Proportion, determines their Force.

4. As the Circumference of the Wheel to that of the Axis that receives the Rope, ſo is the Force gain'd by an *Axis* in *Peritrochio*.

5. The great Friction of the Wedge is overcome by a ſmart Blow. This Friction is of uſe in the Screw, which adds a vaſt Force to the Power, but raiſes the Weight but a little way.

6. If you apply the Screw (call'd in that caſe an endleſs Screw) to the Skew-Teeth of a Wheel, you make a compound Engine of great uſe.

7. Let compound Engines be made in any Form, to know their Strength, obſerve how much the *firſt Mover* goes faſter than the *laſt Mover*; and ſo much as the Effect of the Engine falls ſhort of that Proportion, that is the Friction.

All the mechanical Powers may be reduc'd to the Leaver.

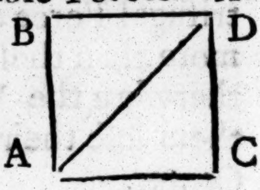
What any Engine gains in Strength, it loſes in Time.

LECTURE

LECTURE IV.

1. THE *first Law of Motion* is this. All Bodies endeavour to remain in their State of Rest or Motion, and that is call'd the *Vis inertiæ* of Matter. Air resists a Projectile, and Gravity brings it to the Ground.

If a Body is acted upon by two Forces, it will go in the Diagonal of the Parallelogram, that represents the quantity and direction of those Forces. As if a Body be acted upon in the Direction A B, and A C, it will go in the Diagonal Line A D, and that in the same time that it wou'd describe A B or A C.



From this Principle, a Cannon-Ball describes a Parabola, by a mixture of the Projectile force of the Powder and the Gravity; the whole Curve being as it were made up of a great Number of very small Diagonals.

2. A *Centrifugal Force*, is that by which any Body moving in a Curve, (as a Stone in a Sling) endeavours to escape out of the Curve, and flie off in a right line Tangent, to the said Curve. The String drawing to the Center, and keeping the Stone from flying off, shews what is meant by a Centripetal Force, which is just the Reverse of the other.

By the Centrifugal Force, a whirl'd Vessel will not spill its Water, because the Gravity of it is less than that Force.

3. The Bullet tied to the Center of the whirl'd Table, endeavour'd at first to remain at rest, whilst the Table went from under it, 'till the roughness of the Table carried it along; which shew'd, that it

endeavour'd to continue at reſt; but when once in motion, it went on, tho' the Table was ſtopp'd, which ſhew'd the endeavour of a Body to continue in motion, and the ſtretching of the String ſhew'd the Centrifugal Force.

4. That ſuch a Force, is ſometimes greater than Gravity, was ſhewn, when the Bullet hung off of the Table, and was rais'd by turning the Table; and alſo when *Mercury*, *Lead* and *Cork*, were carried upward, in their reſpective Tubes, as the Table went round.

5. That Cork in Water, and Oil in Water, went towards the Center, was owing to the greater Centrifugal Force of the Water; becauſe Water weighed more than thoſe Bodies, and had the ſame Velocity; therefore the Water's greater Motion, muſt make them loſe their Places, and force them towards the Center.

That the Motion of the aforeſaid Bodies in the Tubes, was in a *Spiral*, was ſhown by the Spiral, drawn with Chalk, by endeavouring to draw a Semidiameter, whilſt the Table was in motion.

6. If a Cannon-Ball was ſhot Horizontally (or upon the Level) from a Mountain, with a Force of Powder equal to the Earth's attraction, it wou'd conſtantly go round, and never come to the Ground; like a Planet. The *Projectile Motion*, or Centrifugal Force ariſing from it, wou'd keep it from falling to the Earth, and the Attraction of the Earth, wou'd keep it from flying out of its Orbit, and quitting the Earth by moving off in the Tangent.

The *Moon* is juſt ſo affected, but at the diſtance of 60 Semidiameters of the Earth, from the Center of the Earth, and acted upon by an Attraction, about 3600 times leſs than the Attraction or Gravity at the Surface of the Earth; becauſe 3600 is the Square of 60.

7. The

7. The Glaſs Body being whirl'd about on the Table, rais'd Weights that drove it towards the Center, in proportion to the Velocity that was given it, ſo as to encreaſe its centrifugal Force, when it was drawn by the greater Weights: This ſhew'd how Planets are kept from falling into the attracting Sun.

8. The Two Wooden Balls whirl'd about in the Trough, ſhew'd, that when two Bodies are acted upon only by each other, their common Center of Gravity will be at reſt, and they will deſcribe ſimilar Figures round about it.

LECTURE V.

1. THE *Second Law of Motion*, is, that the Change, Encreaſe, or Diminution of Motion, is as the Force impreſs'd, and the Direction of that Force.

2. The *Acceleration* of Bodies in their Fall, is owing to Gravity, and the firſt Law of Motion. Gravity gives the Motion downwards at firſt; the firſt Law continues it, and Gravity ſtill ſuperadds, 'till the reſiſtance of the Air is equal to what Gravity is able to ſuperadd, then the Motion becomes uniform, without any more Acceleration.

3. The more a Body is ſpecifically light, the ſooner it comes to that uniform Motion. Cork immediately comes to it, but Lead is a great while firſt; and the bigger the Lump of Lead is, the longer it falls before it comes to this uniform Motion; becauſe its Weight then bears a great Proportion to its Surface, the reſiſtance of the Air depending upon the latter.

4. The Spaces which Bodies fall thro', are as the Squares of the Times, as is ſhewn by *Galilæo's* Scheme of Triangles, where you ſee, that if a Body falls one Space, (or 16 Feet and one Inch) it will fall four Spaces in 2 Seconds, 9 in 3, 16 in four, *&c.*

5. Where there is no Air, Bodies always accelerate their Motion, in the above given Proportion.

Hence it is, That Comets and Planets in their Ellipſes, move from the *Aphelion* (or greateſt diſtance from the Sun) to the *Perihelion*, (or neareſt diſtance from the Sun) with an accelerated Motion; and from the Perihelion to the Aphelion, with a Motion uniformly diminiſh'd: The Attraction of the Sun, firſt accelerates the Motion, by conſpiring with its Direction, then retards it, by drawing counter to it.

6. The Reaſon why a Planet, or Comet, does not fall into the Sun, when neareſt to it, is, that the Centrifugal Force encreaſes in proportion to the Square of the acquir'd Velocity; and the Reaſon that a Planet, or Comet does not go off, and leave the Sun, when at its Aphelion it is leaſt attracted, is, that the Centrifugal Force diminiſhes in proportion to the Square of the diminiſh'd Velocity.

7. The Orbits of Planets are almoſt Circular; but thoſe of Comets are very long Ellipſes; ſo that they muſt, from the Laws of Gravity, move a great deal faſter than Planets at the Aphelion, and much ſlower at the Perihelion: And that they actually do ſo, is plain from Obſervation; for by a *Ray* drawn by thought from the Sun to them, they ſweep thro' *equal Areas* in *equal Times*; and it has been prov'd, that when a Body revolves about another, if it deſcribes equal Areas in equal Times, it is acted upon by a Centripetal Force, towards that Central Body.

8. That the *Centripetal Force* and Gravity, is the ſame thing in a Second of Time, appears from the

Con-

Confideration, that a Projectile round the Earth, at the Moon's diftance, wou'd move juft as the Moon does, except fome Errors in the Moon's Motion, which are owing to the Sun's Attraction, that difturbs the Motion of the Moon, fo as to make it lefs Regular.

9. Comets receive fuch a degree of Heat, when they come near the Sun, as to fend out a vaft quantity of Vapour, which being fhin'd upon by the Sun, caufes the *blazing Tails*, which we fee of various Shapes, according to our pofition in refpect of them. As the Comets receed from the Sun, they cool, and their Vapour (confequently their Tail) diminifhes.

10. If a Comet fhou'd come fo near the Sun, as to go within its Atmofphere, the refiftance of that Medium, wou'd take off fo much of its projectile Motion, as to make it fall into the Sun in a few Revolutions.

11. Thofe Planets which are neareft the Sun move fafteft, to avoid being drawn into the Sun; and thofe which are fartheft, move floweft, that they may not fly out of their Orbits, as being lefs attracted. The Planets that are near the Sun are fmall, that they may not make the Sun move about a Point far from its own Center; the common Center of Gravity of fuch a Planet, and the Sun being very near the Sun's Center.

LECTURE

LECTURE VI.

1. BY the Light of the Lantern thrown upon the White Ball, was ſhewn how the Light of the Sun falls upon all the Parts of the Moon ſucceſſively. The *Phaſes* of the Moon were alſo ſhewn by it —— The *Full Moon*, when being between the Sun and Moon, the Inhabitants of the Earth ſee all the enlighten'd part of the Moon. *New Moon*, when the Moon being between us and the Sun, its enlighten'd part is turn'd from us. *Half Moon*, when it being in the *Quadratures*, we ſee but half the enlighten'd Part.

2. An *Eclipſe of the Sun*, is, when the Moon being between us and the Sun, the Shadow of the Moon is thrown on ſome Place of the Earth; but as the Moon is leſs than the Earth, and its Conic Shadow much leſs at the Diſtance that we are from it, the Shadow only runs over a ſmall Tract of the Earth, the Inhabitants of which have a *total* Eclipſe; their Neighbours have a *partial* one, becauſe to them the Moon only hides part of the Sun's Body; and all thoſe that are farther remov'd, have no Eclipſe at all.

3. The *Moon's Eclipſe* is, when the Shadow of the Earth falls upon the Moon, and is ſeen by one half of the Earth at the ſame time, *viz.* that Hemiſphere which is turn'd from the Sun. If the Moon is all cover'd with the Shadow, it is a *total* Eclipſe; if not, a *partial* one: If it paſſes thro' the middle of the Shadow, the Eclipſe is *Total* and *Central*, and of *the longeſt Duration.*

4. The Reaſon why we have not Eclipſes every New and Full Moon, is, that the Moon's Orbit being

ing variable, it is not always in the ſame Plane (or Level) with the Earth, at Full and New Moon, its Orbit dipping below, and riſing above the *Ecliptic*, or way of the Earth: But when the *Nodes* (or Places where the Moon's Orbit cuts the Plane of the Earth's Orbit) lie in a Line with the Sun and Earth, there is then an Eclipſe, as alſo when the Moon is very near the Nodes; becauſe the Earth being of ſome Breadth, in reſpect of the Moon's Orbit, may receive the Moon's Shadow, tho' it is not juſt in the Node: Likewiſe the Earth's Shadow, even at the diſtance of the Moon, being of a conſiderable breadth, will eclipſe the Moon, when it is not in the Node; but the Earth's Shadow there, being much ſmaller than the Earth it ſelf, is the reaſon why the *Solar* Eclipſes are more frequent than the *Lunar*.

5. The *Tides* are owing to the Moon's and Sun's Attractions.

The Moon by its Attraction, will cauſe the Water to riſe under it ſelf, and alſo at the oppoſite ſide of the Earth; becauſe at the ſide towards the Moon, the Water being nearer, is more attracted than the Center of the Earth; but on the other ſide, the Water being more diſtant, is leſs attracted than the Center of the Earth. So that the Water makes a *Spheroid* or Egg-form, whoſe longeſt Diameter tends to the Moon. The Sun by its attraction, does the ſame, only its great diſtance cauſes his Spheroid to be ſhorter. When therefore, the Sun, Moon and Earth are in a Line, as at New and Full Moon; the Sun and Moon making their Spheroids in the ſame Line, we have Spring Tides; but when the Moon appears Halv'd, or in *Quadrature* with the Sun, then the Directions of the Sun's and Moon's Forces being at right Angles to each other, the Sun raiſes the Water where the Moon depreſſes it; but not ſo

much

much as the Moon depresses it; so that tho' we have some Tides, they are but low or *Neap* Tides.

6. By Mr. *Graham*'s, the Clock-Maker's Planetary Machine, was shewn the Motion of the Earth and Moon about the Sun, and theirs and the Sun's Motion about their own Axes; as also the Inclination of the Earth's Axis, always the same.

N. B. *The Moon turns about its Axis, just in the same time that it makes one Revolution about the Earth; whence it always shews the same Face to the Earth.* This has made some fasly imagin, that it did not turn about its Axis.

LECTURE VII.

1. IF a Body rolls down several inclin'd Places, whose lowest Part are in the same Level, it will have the same Velocity at the End of them all; tho' it will be longer in falling along the longest Plain, or that which is farthest from the Perpendicular. As for Example, a Body falling from A, will have the same force at E, D and C, and also at B, when it falls down perpendicularly.

If a Body falling along the Plane G H, be turned up again, it will go as high up the Plane H I, allowing for the resistance of the Air, and friction of the Plain.

If a Body falls in the Lines describ'd in the Circle here drawn, they will from C, B, A, D and E, come to F at the same time. Hence is deduc'd the Reason

ſon why a Pendulum makes all its Vibrations, whether long or ſhort, nearly in the ſame time. In the *Cycloid*, the unequal Vibrations wou'd be exactly in the ſame time; which is not only Mathematically Demonſtrated, but deduc'd from a Conſideration of the Attraction of the Earth, being proportionable to its quantity of Matter, and a Corollary from it; by which it appears, that if ſeveral Bodies begun to fall at the ſame time, from the Surface of the Earth, or any Point within the Earth, (ſuppoſing it penetrable) they wou'd come to the Center at the ſame time.

2. Pendulums of the ſame length, let the Ball be of Wood or Lead, *&c.* will make their Vibrations in the ſame time; but the heavieſt Ball will ſwing longeſt.

3. The longer a Pendulum is, the ſlower it vibrates: A *Pendulum* of almoſt 40 Inches, makes a Vibration in a Second of Time, and one of almoſt 10 Inches, ſwings twice in the ſame time, and ſo on; the Time of Swings of Pendulums being Reciprocally, as the Square Roots of their Lengths. The Wire that the Pendulum in Clocks, hangs by, lenthens by Heat, and ſhortens by Cold, as was ſhewn by the Steel Bar, lengthen'd by Heat; ſo that the Pendulums of Clocks muſt be regulated by a Screw. Long Pendulum Clocks go beſt, becauſe the Pendulums deſcribing ſhort Arcs, with a long Radius, make Vibrations very little differing from Cycloidal ones; but at Sea ſuch Clocks cannot be uſeful, becauſe the Motion of the Ship will ſome times make the Pendulum ſwing too long Arcs, which will more deviate from a Cycloid, and ſo be leſs Regular.

4. The Waves of the Sea oſcillate in the ſame time that a Pendulum does, whoſe length is equal to half the Diſtance, between the top of one Wave, and the top of the next. This was ſhewn by Mercury

vibrating in a recurved Tube, in the ſame time that a Pendulum of half the length of the Mercury did vibrate.

Here follows ſeveral Phænomena *of the* Load-Stone.

1. It will attract Iron with one Pole, and repell it with another.

2. It gives a Needle a *Verticity*, or a Tendency to North and South.

3. It is ſtrongeſt when arm'd with Steel Plates.

4. Acts thro' any Body but Iron.

5. Makes Steel-Duſt form it ſelf into Needle-like Figures, which turn over Head, as you turn different Poles of the Stone to them.

6. Steel-duſt let fall upon a Paper, held over a Load-ſtone, places it ſelf in Lines, which ſhew the Direction of the Virtue propagated from one Pole to another.

7. Steel Bodies, by being drawn over the Poles of a Stone, acquire the Power of attracting Iron and Steel; but loſe it, by being drawn over the ſame Pole of the Stone the contrary way.

8. It will, when unarm'd, give Power to a great Key, to draw away a little Key from the Stone it ſelf

New Phænomena of it.

1. A Wire touch'd at one End by a Load-Stone, will have ſeveral Magnetick Points ſucceſſively, call'd *Conſequential Points*; which will alternately be attracted by the North and South Pole, of a touch'd Needle.

2. A Load-Stone has more *Magnetic Points* or Poles, than was imagin'd; but all the North Poles are on one ſide, and all the South Poles on the other; ſo that arming the Stone with Steel Plates, collects the Force of all the Points on one ſide together, and ſo adds to the Power of the Stone.

3. The Upper End of a Steel Bar, attracts the North End of a Needle, and the lower end of it the South

South End, let what end ſoever of the Bar be uppermoſt.

4. The *Variation* is what the Direction of a touch'd Needle differs from a North and South Direction; becauſe the Poles of the Earth are not the Magnetic Poles of it, there being two of them near the North Pole, and two near the South Pole of the Earth.

LECTURE VIII.

1. ELaſticity, or the *Spring* of Bodies, is that Force by which they reſtore themſelves to their Figure, when it has been alter'd by a Blow; and this properly, does not conſiſt ſo much in the Bodies yielding to the Stroke; but in its being perfectly reſtor'd, what ever alteration of Figure it receives.

2. The Stretch'd Cat-gut, which after a Stroke, return'd to its Place with a Sound, ſhew'd what Elaſticity is, and the more tingling the Sound is, the greater the Elaſticity.

3. Glaſs is the moſt Elaſtic of Bodies, as you may know from its Sound, and by letting a Ball of Glaſs fall upon a flat Glaſs Painted over; for then that Glaſs Ball, being flatten'd in the Stroke, receives a Circular Spot of Paint, which is very large in proportion to the Spot which it wou'd have receiv'd, if the Ball had been only preſs'd againſt the flat Glaſs.

4. If there was no Vacuum in Bodies, the Surface of a Glaſs-Ball cou'd never be dented in after the Manner above mention'd; and as there are void

Places in all Bodies, we can have no Body which is perfectly hard, or which is not dented by a Stroke; nevertheless, we may by Experiment shew, what are the Laws of the Congress of hard Bodies; for if we make use of Balls of very soft Clay, which cannot restore themselves after they are dented by a Stroke, they will have the same Property in regard to their Congress, as Bodies perfectly hard; because in the Congress of the Bodies, *not to be dented at all*, is the same as *to be dented, and not restor'd* to the first Figure, which happens to Bodies perfectly Soft; upon which are made the following Experiments, which are true of all Bodies that have no Elasticity, whether they be perfectly Hard, or perfectly Soft.

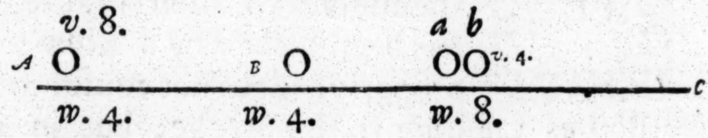
Fig. 1.


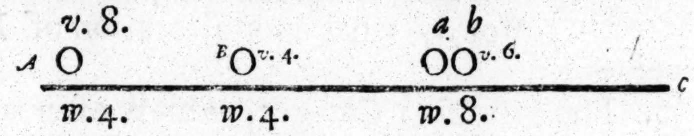
Fig. 2.


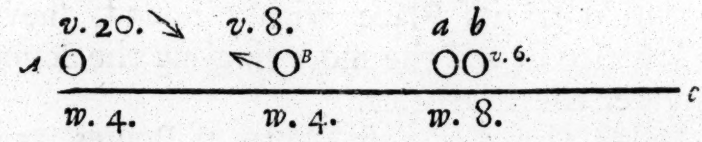
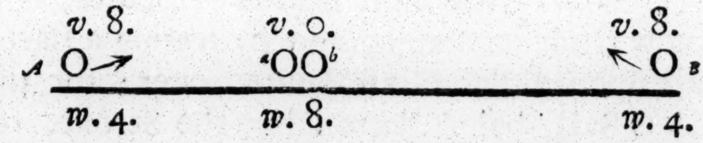
Fig. 3.


Fig. 4.


5. If the Bodies A and B in all the four Figures, are supposed to weigh equally, as for Example, four *Pound* each, it will happen, that if A has 8 Degrees of Velocity, and strikes B which is at rest, after the Blow A and B, will go together towards C, with half the Velocity of A, *Fig.* 1. where *w* denotes the

the Weight of the Bodies, as it does alſo in all the other Figures.

6. If A has 8 Degrees of Velocity, and B 4, after the Shock both Bodies will move towards C, with half the Sum of the Velocities, that is with 6 Degrees, *Fig.* 2.

7. If A moves towards C, with 20 Degrees of Velocity, and B towards A, with 8 Degrees of Velocity, both Bodies will go together towards C, where there is moſt Motion, with half the difference of their Velocities, that is, with 6 Degrees of Velocity, *Fig.* 3.

8. If A and B meet each other with equal Velocities, they will loſe all their Motion after the Stroke, ſee *Fig.* 4.

9. *Laſtly*, If the Bodies are unequal, and move towards the ſame Parts, you muſt add together their Quantity of Motion, which dividing by the Sum of the Weight of the Bodies, you will have the Velocity, with which they will go on together after the Stroke: But if the two Bodies have contrary Motions, they will go after the Stroke, towards the way where there is moſt Motion; and ſubtracting the leaſt quantity of Motion from the Greateſt, divide the remainder by the Weight of both Bodies, and you will have their Velocity.

10. If from the Center of a Quadrant, two Elaſtic Bodies of equal Weight hang by Threads, when you raiſe each of them up to an equal Number of Degrees from the Bottom, they will meet at the bottom, and return to the height from whence they came. By the Stroke they loſe all their Motion; but as they are dented in proportion to the Force of the Stroke, in reſtoring themſelves, they will drive each other back with the ſame Velocity, that they had before the Stroke.

11. By the ſame Principle, if an Elaſtic Body in Motion, ſtrikes another Elaſtic Body equal to it, which is at reſt, the Firſt will remain at reſt in the Place of the Second, and the Second will go on with all the Velocity of the Firſt.

12. If two Elaſtic Bodies ſtrike each other, having different Velocities, whether they meet, or overtake each other, they will interchange Velocities at every Stroke.

The latter Part of this Lecture was concerning the Strength of our Bodies, well applied.

One Man with a ſtrong Girdle round him, a little below his Hips, (that is juſt reſting on the two *Trochanters* of the Thigh-Bones) and ſitting upon a Plane, riſing a little above the Horizon juſt at his Feet, which bear againſt a fix'd Vertical Plane, will be able to maintain his poſition againſt ten Men, or two Horſes, which pull him by means of a ſtrong Rope fix'd to the Iron Hook of his Girdle; becauſe the Legs and Thighs lying in a right Line upon the Plane, the Horſes muſt draw at a very acute Angle; and it has already been demonſtrated, that when a Power acts at a very acute Angle, it draws with great Difficulty.

The other Experiments of Strength that were ſhewn, depend upon the ſame Principles.

LECTURE

HYDROSTATICKS.

LECTURE IX.

1. A *Fluid* is a Body that yields to any Force Impreſs'd, and ſo recedes moſt from the Greateſt Preſſure.

2. That a Fluid weighs in its own *Element*, was ſhewn by Water's weighing in Water, and Air in Air, as appeared by Experiment.

3. A Drop of Water, on a Table, preſs'd by the Finger, not only acts againſt the Table, and Finger, but alſo ſpreads laterally every way.

From theſe Propoſitions is deduced, 1*ſt*. That all the Parts of Fluids are heavy. 2*dly*, That the Upper preſs upon the Lower. 3*dly*, That the Higher the Fluid is, the more the bottom of the Veſſel is preſs'd with it. 4*thly*, That the Preſſure of the Fluid, againſt any Part of the Side of the Veſſel, is according to the Height of the Fluid above that Part. 5*thly*, That all the Parts of an Homogeneous Fluid are at reſt; each Part being as low as it can be. 6*thly*, That not only the upper Surface, but every *Imaginary Surface*, (or Surface ſuppoſed in any Part of a Veſſel) muſt be equally preſs'd in all its Parts; which makes the Upper Surface be always level; becauſe otherwiſe an Imaginary Surface

face in the Fluid, wou'd be unequally preſs'd; but the Parts more preſs'd than the reſt, muſt yield and ſink down, and the Parts leſs preſs'd than the reſt, be forced upwards.

4. One Body is *Specifically* heavier than another, when it has *more Matter with the ſame Bulk*, or *as much Matter with a leſs Bulk*.

5. A Pillar of Water in a Tube, was ſuſtained in a Veſſel of Oil; but ſtood lower in the Tube, than the Surface of the Oil; becauſe it preſs'd but juſt as much upon the Imaginary Surface, as the like Pillars of Oil round about it, being as much ſhorter than them, as *Water* is Specifically heavier than *Oil*; if the Water was brought up to the Surface of the Oil, it wou'd ſink, ſome Drops coming out at the bottom of the Tube: Again, if the Tube was put down, ſo as to ſink the Water lower, below the above-ſaid Proportion, the Water wou'd riſe, and the Surface reſt at the firſt Place. In like manner, Pillars of Oil in Tubes, will ſtand higher than the Surface of the Water, in which they are Immerſed, and riſe, if the Tube be plunged deeper; but deſcend, (ſome Drops falling out at the bottom of it) if the Tube be raiſed, ſo as to make the Pillar of Oil too long in Proportion to the Counterpoiſing Pillars of Water, that preſs on the Imaginary Surface, at the bottom of the Tube.

6. By ſuch kind of Experiments, with Red Water in Tubes of various Shapes, it appeared, that Fluids preſs upwards, downwards, ſidewiſe, and in any Direction according to their Height.

7. A Body Specifically heavier than Water, will ſink in Water; becauſe where ever you put it, it weighs more than the Water, whoſe Room it takes up, and ſo the Surface immediately under it, being more preſs'd in that Part which ſhou'd ſuſtain the ſaid Body, than any where elſe, yields, and lets it fall

fall thro': But a Body ſpecifically lighter than Water will riſe, becauſe it preſſes an Imaginary Surface leſs than the Water, in whoſe Room it is ſubſtituted; and therefore muſt be forced upwards.

8. A Piece of Lead ſwims in Water, by keeping the Water from preſſing upon the Lead, and plunging it near twelve times its Thickneſs under Water before you let it go; but it will fall down, when you raiſe the Veſſel to which it is apply'd, ſo as not to let the ſaid Lead be ſo deep under the Surface of the Water, as twelve times its thickneſs. The Rule to make any Metal ſwim in that manner, is, to plunge it ſo much deeper than its own thickneſs under Water, as that Metal is ſpecifically heavier than Water, always keeping the Water from getting above it. As Gold muſt be above nineteen times its thickneſs under Water to ſwim, becauſe 'tis nineteen times heavier than Water, *&c.*

9. A Body ſpecifically lighter than a Fluid, may be kept down at the bottom of a Fluid, if the bottom of the Veſſel be ſmooth, and the Body being likewiſe ſmooth, lies ſo cloſe to it, that none of the Fluid gets between; but if the leaſt paſſage be made for the Fluid, it will quickly inſinuate it ſelf between the Body and the bottom of the Veſſel, and make the Body riſe to the top of the Fluid: The Experiment was ſhewn by a Piece of flat Glaſs lying at the ſmooth Bottom of a Jar of Mercury.

LECTURE X.

1. A Body ſpecifically heavier than Water, loſes of its Weight in Water, as much as the Weight of an equal Bulk of Water; and what the heavy Body loſes, the Water gains, as appear'd by the Experiment of the Lead, weigh'd firſt in Air, then in Water.

2. The different ſpecifick Gravity of Fluids, may be known by weighing a piece of Lead (or any Body ſpecifically heavier than the ſaid Fluids) ſucceſſively in all of them; that being lighteſt, in which it loſes moſt of its Weight.

3. The ſpecifick Gravity of ſolid Bodies heavier than Water, may be found, by weighing them ſucceſſively in Water; that being ſpecifically heavier, which loſes leaſt of its weight in Water. Pure Gold loſes only a 19th part of its Weight in Water. N. B. *On theſe Principles depends the* Hydroſtatical Balance.

4. If a Lump of Lead, and a Lump of Braſs, be equipois'd in Air, the Lead will preponderate, when they are both weigh'd in Water; and thus you may know a bad Guinea from a good one.

5. As the Weight of a heavy Body in Air, to its of loſs Weight in Water; ſo is the ſpecifick Gravity of the Body, to the ſpecifick Gravity of the Water.

6. A Body ſpecifically lighter than a Fluid, will ſwim a top; and in ſuch a Caſe, a Bulk of Water, equal to the immers'd Part of the Body, will weigh as much as the whole Body; which muſt needs be, otherwiſe the Imaginary Surface under the Body, wou'd not be equally preſs'd in all Parts. *This was ſhewn by the Experiment of the double Cone of Wood weigh'd againſt Water.*

7. Bodies

7. Bodies that ſwim in Water, have their ſpecifick Gravity in reſpect to each other, as their Parts immers'd in the Water.

8. A Body ſpecifically lighter than any Fluid, ſinks deepeſt in the lighteſt Fluids; and hence it is, that the *Hydrometer* (or *Water-poiſe*) ſhews the different ſpecifick Gravity of Fluids.

9. A Body of the ſame ſpecifick Gravity as Water, will reſt in any place of a Veſſel of Water.

10. The Preſſure of a Fluid, upon the bottom of any Veſſel, (be the top Wide or Narrow) is as much as the Weight of a Pillar of that Fluid, of the Height of the Fluid, and of the Bigneſs of the Baſe all the way; which was ſhewn by ſeveral Experiments, eſpecially one, by which a Pint of Water in the Tube of the *Water-Bellows*, ſuſtain'd the whole weight of a Man.

If you blow into the ſaid Machine, your Breath will raiſe a Man ſtanding upon it; becauſe the Force of the Blaſt is encreas'd in proportion, as the Surface on which a Man ſtands, is greater than the Hole which you blow in at; provided that Hole be not wider than the Section of the Wind-Pipe.

11. Water brought from a Reſervatory, will riſe as high in Pipes, as the Surface of the Water in the Reſervatory; but not ſo high in *Jettos*, on account of the Reſiſtance of the Air, and Friction of the *Ajutages*.

12. The lower you tap a Veſſel, the further the Liquor will ſpout; becauſe the Preſſure being according to the Height, it is then forc'd out with the greateſt Velocity.

But if a Plane intercepts the ſpouting Liquor, a Hole being made in the Veſſel, exactly in the middle, between the Surface of the Liquor and the ſaid Plane, the Water will ſpout fartheſt from ſuch an Hole.

13. If equal Holes be made in a Veſſel, at different heights, the Expence of the Water will be as the Square Roots of the different Heights of the Surface of the Water above the Holes.

LECTURE XI.

1. WHEN a Bubble of Glaſs, with the open Mouth hanging downwards, is ſo far fill'd with Water, as but juſt to ſwim at top of a long Glaſs Veſſel full of Water, if you puſh it down to the bottom of the Veſſel it will not riſe again; and if afterwards you lift it up to the top, it will not ſink again; becauſe, tho' the Air that was in the Bubble (when at top) hinder'd the Atmoſphere from preſſing any more Water into it; (to make it ſpecifically heavier than Water, and ſo ſink) yet when the Bubble was puſh'd to the bottom, the Atmoſphere, help'd by all the height of Water in the Veſſel, compreſs'd the Air within the Bubble into a leſs room, ſo that the Water coming in, made the Bubble ſpecifically heavier than Water, and therefore it kept at bottom; but when the Bubble was brought to the top of the Water, the Air in it being no longer compreſs'd by the additional Weight of the Water in the Veſſel, expanded to its former tenour, and ſo forcing out the additional Water that was got into the Bubble, the Bubble was made ſpecifically lighter than the Water, and remain'd at top. As there was a certain height from which the Bubble wou'd emerge, beyond which it wou'd always fall; this Experiment is a farther Proof, that Water preſſes according to its Height.

It is upon this Principle, that Glaſs Images riſe and fall in Water; but with this Exception, that they are too light to be made ſpecifically heavier than Water, by the Weight of the Water in the Veſſel only; and therefore a Bladder being tied over the Surface of the Water, the Hand which preſſes upon the Bladder, forces Water into the Images, and makes them ſink; but upon the Removal of that Preſſure, the Air in the Images forces out the Water by its expanſion, and they riſe again.

2. In a recurv'd Tube, with the Holes upwards, one Inch of Mercury will keep in Æquilibrio 14 Inches of Water, as being 14 times heavier.

3. That Water riſes in any Tube above its Level, as in ſuction by the Mouth, or by a Pump, is owing to the Weight of the Atmoſphere, which preſſes more upon the Surface of the Water in all the other Parts, than in the Middle, where the Air is rarified, or taken away; as was ſhewn by a Sucking-Pump.

N. B. *In all Pumps, all the Valves or Clacks open upwards, that the riſing Water may not fall back again.*

4. Taking the Air out of a *Crane* or *Syphon*, whoſe ſhorteſt Leg is in a Veſſel of Water; the Water will riſe, and continue to run out at the longeſt Leg; becauſe the Air which preſſes upon the Water in the Veſſel, and makes it riſe in the ſhort Leg, has leſs weight to ſuſtain, than the Air which acts upwards, againſt the Water running out at the longeſt Leg; and therefore, the firſt Air overcoming the laſt, makes the Water conſtantly run.

5. If a *Bolt-Head* full, or nearly full of Water, be inverted into a Glaſs of Wine, the Wine and Water will change Places; becauſe the Water is ſpecifically heavier than the Wine.

6. Mercury will run from one Veſſel to another by a Syphon, as well as Water; but the Bend of the

Sy-

Syphon muſt not be more than 31 Inches above the Surface of the Mercury; as in Water-Syphons, the Bend muſt not be above 35 Feet above the Surface of the Water: For the Atmoſphere, which cauſes the Fluid to riſe, can ſuſtain no more than 31 Inches of Mercury, and 35 Feet of Water in height at moſt. So the Water in Sucking-Pumps, can riſe no higher than 35 Feet ſtrictly ſpeaking; tho' in Practiſe it is ſeldom ſuck'd above 28.

This ſhews, that in Suction there is no ſuch thing as Nature's abhorrence of a Vacuum, *to cauſe the Aſcent of Liquors.*

LECTURE XII.

1. THE *Steam* or Vapour of Water excited by Fire, is made uſe of to raiſe Water in *Captain Savery*'s Hydraulick Engine, in the following manner.

By opening a Cock, throw the Steam of the Water boiling in the Globular Copper or *Æolipile*, into the Receiver or ſucking Veſſel, which will drive the Air out of it, thro' the *Valve* in the *Pipe of Conduct*: then having ſhut the aforeſaid Cock; by a ſmall Cock in a little Pipe from a Ciſtern of cold Water, let in a jet of cold Water into the Receiver to cool it, and condenſe the Steam, which being turn'd into a ſmall quantity of Water, leaves all the reſt of the Receiver quite empty; ſo that the Atmoſphere eaſily forces up the Water into it, thro' the Valve of the ſucking Pipe. Shut the Jet, and let in the Steam to drive up the Water, then ſtopping the Steam, condenſe it by the Jet, and the Atmoſphere will

will puſh up the Water from the Well below, as before in the Receiver, which may again be driven up by the Steam, *&c.* —— *Two Receivers may be work'd in the ſame manner.*

2. *Air* is a Fluid conſiſting of Parts that drive each other away from their reſpective Centers; becauſe it has been found by Experiments, that its Denſity is equal to its Compreſſion, and Sir *J. Newton* has demonſtrated, that ſuch a Fluid muſt conſiſt of Parts that have a *Centrifugal* Force.

3. The Air near the Earth, is in a compreſs'd State, by reaſon of the great Weight of the Air above it; the *Atmoſphere* is no highter ſenſible, than about 45 Miles, as is ſhewn by conſidering how high the Mercury muſt ſtand in the Barometer, at different heights above the Surface of the Earth.

4. The Air always endeavours to continue of the ſame Tenour; if it be any where condens'd, or rarified in one Place, when left to it ſelf it will return to its former denſity. It is on this Principle, that Artificial Fountains are fill'd and play. As for Example, let the Glaſs Bottle in this Figure  have a Tube cemented to its Mouth, ſo as to have no paſſage left for the Air into the Ball, or out of it, but thro' the Holes at its Ends *a* and *b*: If you ſuck at *a*, ſo as to rarifie the Air in the Ball, and having ſtopp'd *a* with your Finger, you immerge that Part of the Tube under Water, the Water by the preſſure of the Atmoſphere will riſe into the Ball thro' the Tube, 'till the Air that was left in the Ball is condens'd to its firſt Tenour: Then if you blow hard into the Ball thro' *a*, the Air which you condenſe into the upper Part of the Ball, having no way to come out directly, will dilate it ſelf, 'till it comes to its firſt Tenour, and in ſo doing, force the Water out in a Jet, in proportion to the room that it expands it ſelf into.

5. All

5. All Fountains, into which the Air or Water is injected by a Syringe, which ſpout 30 or 40 Foot high, are actuated by this Principle.

6. The *Artificial Lungs*, made of a hollow Glaſs Hemiſphere and two Bladders, ſhew'd the manner of Breathing; for as the Air in the Cavity of the *Thorax*, betwixt the *Lungs*, and the *Pleura* is expanded, and ſo rarified, when that Cavity is encreas'd by the raiſing of the Ribs, and ſinking of the *Diaphragm*, the external Air will ruſh into the Lungs, and raiſe them up, 'till they contract the enlarg'd Cavity of the Thorax, ſo as to render the Air in it of the ſame tenour as before, and this is call'd *Inſpiration*. *Expiration* is thus perform'd; by the Muſcles of the Belly, the Inteſtines are rais'd up, ſo as to make the Diaphragm come upwards, by puſhing up againſt it; then the Ribs alſo ſubſiding, the Air in the Thorax is condens'd, and ſo being made ſtronger than the Air in the Lungs, which is of the ſame Tenour as (and communicates) with the external Air, the Lungs are depreſs'd, and made to diſcharge their Air, 'till the Air in the Thorax has expanded to its firſt Tenour.

7. Upon this Principle are made *Hero*'s Fountains, as the *Fountain of Command*; the *Fountain by Attraction*; the *Fountain by the Compreſſion of Air*, *by the Fall of Water*, to imitate a perpetual Motion, *&c.*

8. If a Cupping-Glaſs be held over the Flame of a Lamp, then immediately apply'd to any part of the Body, ſo as to touch the Skin in all Parts of the Mouth of the Glaſs, the Fleſh will riſe within the Glaſs; becauſe the rarified Air in the Glaſs, having leſs Force than the Spring of the Air in the Fleſh, muſt ſuffer the Fleſh to riſe by the Expanſion of the Air within it.

For this Reaſon, when you have thrown a flaming piece of Paper in a Glaſs Jar, if you immediately invert

invert it in a Baſon of Water, upon the going out of the Fire, which made the Air in the Jar continue in a ſtate of Rarefaction, the Atmoſphere will force up the Water into the Jar, 'till the Air is reduc'd into ſuch a ſmall Space, as to become of its firſt Denſity or Tenour.

Water will not run out of an inverted ſmall Tube, or out of a narrow Mouth-Bottle, becauſe the Air acts upwards againſt it, without being able to ſlip by the ſide of the Water, to get to the top of the Water to preſs it down.

9. If to the Blank Screw, with which you ſhut up the Hole of a very tight Syringe, whoſe Bore is equal to a Square Inch, you hang a Scale with ſo much weight in it, that the whole amounts to 14 Pounds and an Ounce, *Averdupoiſe*, the Weight of the Atmoſphere, that keeps the Piſton cloſe to the bottom of the Syringe, will hinder that Weight from drawing them aſunder, when the Mercury in the Barometer ſtands at 28 Inches; but a little more Weight will bring down the Syringe from the Piſton: If the Mercury ſtands at 31 Inches, the Syringe will not be drawn down with leſs than 15 Pounds and 11 Ounces, and a little more.

From this Experiment may be known, what weight of Air preſſes upon a Surface, equal to a Square Inch, at any height of the Barometer, or ſtate of the Atmoſphere; and the *Syringe* it ſelf, in this Caſe, becomes a *Barometer*.

10. If we know how much Surface a Man's Body has, we may know how much Air preſſes upon our Bodies at any time; as for Example: Suppoſe a Man's Skin has 15 ſquare Feet of Surface; then ſince 15 Pounds and 11 Ounces preſſes upon an Inch, if that be multiplied firſt by 144, the Inches in a Square Foot, then by 15, the Feet contain'd in the Skin, we ſhall have 33905 Pound and a half, for

 the

the Air pressing upon the Body, when the Mercury stands at 31 Inches, or when the Air is heaviest; and if 14 Pounds and an Ounce be multiplied by the above-said Numbers, we shall have 30624 Pounds, or the Weight of the Air upon the Body, when the Mercury stands at 28 Inches, or the Air is lightest.

LECTURE XIII.

1. THE best Method of Diving is by the Bell, which is a Wooden Machine, shap'd like a Bell, and hung at the Bottom with heavy weights of Lead to make it sink; the Air in it keeps out the Water, so that Men that sit in it, may be let down to the bottom of the Sea without danger; but as the Air in the Bell is compress'd by the Water in proportion to the Height of the Water above the Bell, the Water will rise in the bottom of the Bell in that proportion; so that at the depth of six Fathom, the Air being condens'd into half the Space which it had at first, will suffer the Water to fill half the Bell; at the depth of twelve Fathom, two Thirds of the Bell, *&c.* So that at great depths there wou'd be but little room in the Bell; but Dr. *Halley* found a Means to take in Air let down in Barrels, which had a Contrivance to let the Water into the Barrel at bottom, whilst the Air of the Barrel went into the Bell, and this being often repeated at any depth, the Water of the Sea wou'd be hinder'd from coming above an Inch or two in the bottom of the Bell: But as Air often breath'd will be effoete, and unfit for respiration, he found a means to let out that

that Air by a Cock at the top of the Bell, changing it for the fresher Air, which he took in at bottom from the Barrels, and that was done without difficulty, because when Air has been rarified by passing thro' the Lungs, it will by its lightness get to the top of the Bell. As for the coming in of the Water, it cou'd only be at bottom, whilst some Air was let out at top; because the Pillars of Water pushing in at the bottom of the Bell, were longer, and consequently heavier than the Pillar pressing upon the Top, where the Air came out thro' so narrow a Passage, that the Water cou'd not slip by at the same time. Another thing to be taken care of is, not to be let down suddenly to any great Depth, because the Air in our Flesh, being only a Balance for the common Air, wou'd not be able to sustain the encreas'd Pressure; but if a Man be let down by degrees, he will breath the compress'd Air, which circulating with the Blood, will enable the Body to sustain the great Pressure at the bottom of the Sea, as easily as we sustain the Weight of the Atmosphere above ground; to keep this Ballance of the Air within, and the Air without, care must also be taken, that the Bell be not pull'd up from a great Depth suddenly to the top of the Water. See Dr. *Halley's own account of it, in the* Phil. Transactions, *Num.* 349.

2. From the Pressure of Water, encreasing in proportion to its depth, it is evident, that such Divers as breathe the Air from above the Water, by a Pipe fix'd at the top of the Armour over their Heads, cannot go down to great depths, since they breath only an Air, whose spring in their Flesh is but able to sustain the common weight of the Atmosphere.

3. *Weather-Glasses* are Instruments made use of to determine the State of the Air at any time. Its weight is determin'd by the *Barometer*; its Heat or

Cold by the *Thermometer*, and its Moiſture and Dryneſs by the *Hygrometer*.

4. To make the Barometer fill a Glaſs Tube of about a quarter of an Inch Diameter, three Foot and a half long, and hermetically ſeal'd at one end, (that is clos'd with the Glaſs it ſelf melted) and having fill'd it with very fine Mercury, and got the Bubbles of Air out from the Mercury in the Tube, hold your Finger hard upon the open end, and having inverted the Tube thus fill'd, into a Glaſs Ciſtern of Mercury, ſo that your Finger that ſtops the Tube may be under the Surface of the ſtagnant Mercury, then taking away your Finger, the Mercury will fall from the top of the Tube, and reſt at the Height of between 28 and 31 Inches above the Surface of the Mercury in the Ciſtern; it will ſtand higheſt when the Air is heavieſt, and loweſt when the Air is lighteſt. The Height of the Mercury in the Tube will be the ſame, whether the Tube be upright or inclin'd, large or ſmall; becauſe all Fluids preſs according to their Height. If therefore, Degrees are mark'd upon the Frame of the Barometer, great care muſt be taken, that the Barometer be ſuſpended perpendicularly.

5. The Reaſon why, when the Mercury in the Barometer ſtands high, it is fair Weather, is, that upon an additional quantity, or accumulation of Air over any Place, the lower Air being more compreſs'd, becomes ſpecifically heavier than before, and the Clouds which ſwam in it, being made by that means, ſpecifically lighter than the Medium in which they are, muſt riſe 'till they come to an Air of the ſame tenour with themſelves. This happens either when two contrary Winds blow towards any Place, or one Wind is check'd by a Ridge of Mountains, ſo as to make an Accumulation of Air over the Place where the Barometer is.

6. When

6. When contrary Winds blow from the ſame Place, the Air at top being carried away, preſſes leſs upon the lower Air than before, and the Clouds deſcend to come into an Air of the ſame ſpecifick Gravity: Now if this change of Gravity be conſiderable, the Clouds will fall quick, and by the reſiſtance of the Air, be condens'd into Rain; and thus the deſcent of the Mercury in the Barometer, ſhewing the diminiſh'd Weight of the Atmoſphere, which is the Cauſe of Rain, foretells foul Weather.

7. In Storms the Mercury falls, as was ſhewn by the Artificial Wind made to blow over the Ciſtern of a Barometer. —— The Experiment call'd Monſieur *Auzout*'s, with a double Barometer and two Ciſterns, plainly ſhews, that the Mercury in the Barometer, is only ſuſtain'd by the Air: It is alſo plain, from the Barometer's being put into a Receiver upon the Air-Pump; for when you draw out all the Air, the Mercury in the Tube comes quite down, and riſes again to its uſual height, upon the readmiſſion of the Air.

8. The Thermometer is made of a Glaſs Tube, with a hollow Ball at one end of it, and the other hermetically ſeal'd, with Spirit of Wine in the Ball and part of the Tube, the reſt of the Tube having no Air in it; ſo that the Spirit of Wine may without hindrance, be rarified by Heat, and condens'd by Cold, which will appear by its riſing or ſinking in the Tube.

9. Air-Thermometers are Tubes with Balls at top, and open at bottom, which having the Tube half full of Water, ting'd with ſomething to colour it, ſtand in a Ciſtern of the ſame Liquor, that riſes and falls in the Tube, according to the rarefaction, or condenſation of the Air in the Ball; but ſuch Machines are not juſt Thermometers, becauſe as they have a Communication with the outward Air, they

they muſt be affected with its encreas'd or diminiſh'd Gravity, which will cauſe the Liquor ſometimes to riſe or fall more than it ſhou'd do, and ſometimes not enough: But as this Error is owing to no other Cauſe, than the Alteration of the Air's Gravity; from this kind of Thermometer, and the Spirit-Thermometer compar'd together, we may at any time know the Gravity of the Air, as well as by the Mercurial Barometer, for the difference of the riſe or fall of the Liquor in the two Thermometers compar'd, will always be proportionable to it. Upon this Principle, was invented an Inſtrument, made by the Combination of theſe two Therometers, call'd a *Marine-Barometer*, which is uſed at Sea; becauſe the ſhake of the Ship, which gives ſuch Vibrations to the Mercury in the common Barometer, as to render it uſeleſs, cannot affect this.

10. The Hygrometer meaſures the Moiſture and Dryneſs of the Weather, and is made ſeveral ways. Take a twiſted ſmall Cord, and hang it looſly upon two Nails, ſo that it makes a Curve, and by a Graduated Perpendicular, find how much the String riſes as it ſhortens by moiſture, or ſinks as it lengthens by dryneſs. A Beard of a Wild Oat will twiſt and untwiſt by Dryneſs and Moiſture, ſo that an Index being fix'd to it, will render it a good Hygrometer. N. B. *For the moſt part Animal Subſtances, as Parchment, Leather,* &c. *ſhorten in dry Weather, and lengthen in wet Weather.*

LECTURE XIV.

1. THAT the Spring of the Air is equal to its Weight, is shewn by the Experiment of the Mercury rais'd in the open Tube screw'd into a Bottle, when by exhausting the Air-Pump-Receiver, the Spring of the Air in the Bottle, forc'd up the Mercury from the bottom of the Bottle into the Tube, to as great a height as it stands in the Barometer.

The other Experiments upon the Air-Pump, (which are describ'd at large in the little Book written by the maker of the Pump, that gives the Description of it) shew,

1*st*, That there is Air in our Flesh and in all Liquors.

2*dly*, That the Air near the Earth is capable of a very great Expansion.

3*dly*, That Air is the Vehicle of Sound, the Sound ceasing where there is no Air.

4*thly*, That Air is the Food of common Fire.

5*thly*, That Phosphorus and Electrical Light, is help'd by the Absence of the Air.

6*thly*, That Air is not necessary for the Ascent of Liquors in small Tubes.

7*thly*, That the Resistance of the Air is the cause of the Explosion of Gun-Powder, which only fires Corn by Corn, in a Vacuum.

8*thly*, That what was attributed to Nature's *Abhorrence of a Vacuum*, is only owing to the Air's Pressure; a Syringe not sucking up Liquors *in Vacuo*, and Exhausted Hemispheres, or Polish'd Plates of Marble (which stuck together in the open Air) dropping asunder *in Vacuo*.

9*thly*,

9thly, That Air becomes poisonous in passing thro' the Flame of Charcoal or Spirit of Wine, and thro' red hot Brass; but not thro' red hot Iron or Copper.

10thly, That Heat and Cold will be communicated to Bodies in a Vacuum.

11thly, That Square Glass Bottles are not able to sustain the Air's Pressure, tho' round Glasses are; because the Corners of Square Bottles, being stronger than the other Parts, the Air's Pressure is less resisted by the Sides, which have only their mutual coherence to hold by; whereas in a round Glass, all the Parts, as in an Arch, sustain one another, and the Pressure upon them is uniform.

LECTURE XV.

1. AIR Condens'd will expand it self with the same Force with which it was compress'd, and in so doing, it will drive a Body strongly, as in the Case of the Wind-Gun, which will throw a Bullet thro' an Inch Board.

2. When the Air is drawn from between two Hemispheres of three Inches and a half Diameter, it requires a Force equal to 140 Pounds, to draw them asunder. Now if the said Hemispheres, without drawing the Air from between them, be put together in the condensing Glass, upon injecting so much Air, as to double the Density of the Air in the Glass, (as may be known by the included Gage) it will require the same weight of 140 Pounds to draw them asunder, which shews, that no Imaginary

Power of Suction, but the Preſſure of the Air keeps the Hemiſphere together.—— If the Hemiſphere be exhauſted before they are put into the Condenſing Glaſs, when by injection the Air in the Glaſs is doubled in denſity, a Weight of 280 Pounds will be required to draw them aſunder. So that it appears, that *doubled Air* has the ſame advantage over *ſingle Air*, as *ſingle Air* has over a *Vacuum*.

3. Phoſphorus will be put out by injecting Air upon it; the Vibrations of its Parts, (which throw off luminous *Effluvia*) not being able to overcome the additional Preſſure of the Air; much leſs Air than what doubles its denſity will produce this Effect, and exhauſting the Glaſs will add to the brightneſs of the Light.

4. In the Braſs condenſing Engine, a Bell will ſound louder, by condenſing the Air about it, and a round Bottle will be broken by the injected Air, tho' it will bear being exhauſted by the Air-Pump. Few Animals will die in this Engine, becauſe the Air being injected by degrees, they breath the Air as it is condens'd, and it circulates with their Blood, ſo as to enable the Animal to ſuſtain the encreas'd Preſſure.

OPTICS.

LECTURE XVI.

1. THAT *Light* is a Body, appears from its *Reflection*, *Refraction*, *Composition*, *Division*, and *moving in Time*; but especially from its being *propagated in right Lines*, and being *stopp'd by an Obstacle*, (how thin soever, if not transparent) which shews, that it cannot be an *Action upon the Medium*, which wou'd be communicated beyond an Obstacle, as in the case of Sound.

2. *Lucid Bodies* emit Light, *transparent Bodies* (call'd also the *Medium*) transmit it, and *opaque Bodies* reflect it.

3. Since an opaque Body reflects Light, so as to send it from all its Points every way, as a lucid Body does, (tho' not so copiously) it may be call'd a *Radiant*, as well as a lucid Object, and projects its Image in the Eye in the same manner.

4. Every Surface has the Images of all Objects, that can send Rays to it, painted upon it; but the Mixture of them all, hinders us from distinguishing any one. To prove this, if you hold a Paper over-against the Hole of a dark Room, the external Objects will paint their Images upon it so that they will be seen distinctly, because by darkning the Room, you cut off all the Rays which wou'd come from the Objects on the sides to make a Confusion.

5. The

5. The Pupil of the Eye, is inſtead of the Hole of the dark Window, to hinder a Confuſion, by the reception of too many Rays.

6. When, of thoſe Rays, which diverge from one Point, thoſe that fall upon a double convex Glaſs, or any tranſparent Body of the ſame kind and figure, will after paſſing the Glaſs, be refracted ſo as to meet in a Point on the other ſide of the Glaſs, and make two Cones of Rays, whoſe Baſes joyn at the Glaſs. Such a Parcel of Rays is call'd a *Pencil of Rays.*

7. If diverging Rays fall upon a concave Looking-Glaſs, they will be reflected ſo as to meet on the ſame ſide of the Glaſs, and the reflected Cone will either coincide with the other, or elſe meet nearer to the Glaſs, or farther from it than the Point of Divergence. We ſhall alſo call this a Pencil of Rays.

8. In *Catoptrics*, or Viſion by Reflection, there is only one Principle, which if well underſtood, and conſider'd in all its Caſes, comprehends the whole Doctrine; and that is, *That the Angle of Incidence is equal to that of Reflection*; by which is meant the Angle made by the incident Ray and a Line perpendicular to the reflecting Surface falling upon it at the Point of Incidence, and the Angle made by the reflected Ray and the ſaid Perpendicular.

9. When diverging Rays fall upon the Eye, ſo as to paint the Image of any Point of an Object; if by Thought you produce back thoſe Rays 'till they meet in a Point, that Point will be the Place where the above-ſaid Point of the Object is ſeen, whether that be the real Place of the Object or no. Hence it is, that an Object appears to be behind a Looking-Glaſs, tho' it really is before it; becauſe the Rays, after reflection, fall upon the Eye in the ſame manner, as if they came directly from a Point behind

the Glass. The Point where the Rays meet is call'd the *Focus* of those Rays.

10. The same position that an Object has in respect of a *Mirrour* or Looking-Glass, the same has its Image.

11. An Image (as if it was an Object) will project another Image of it self; whence we see a great Number of Images of one Candle, reflected backwards and forwards, by means of two Mirrours. One Candle will also give a row of Images, by means of one Mirrour, when you look Obliquely; the two Surfaces of the Glass performing the Office of two Mirrours.

12. In a Convex-Mirrour, the Object seen by Reflection, appears smaller, and nearer behind the Glass; because after Reflection, the Rays diverge more than from a plain Mirrour; so that the Focus of every Parcel of reflected Rays, which came from every Point of the Object, is nearer to the Glass behind it, and therefore all those *Foci* are nearer to each other, and consequently an Object thus seen, appears less.

13. In a Concave-Mirrour, the reflected Rays diverge less than they wou'd from a plane one; therefore the Object appears magnified, and farther behind the Glass.

Hence may it be known at any time, whether Polish'd Metal or Glass be truly flat, by observing whether the Image of the Face, seen by Reflection, is neither magnified nor diminish'd: So by observing the Image from the two Convex Surfaces of a Lens, you may know which side is most convex, by its reflecting a less Image than the other.

14. If Parallel Rays (as for Example, the Sun's Rays) fall upon a Concave Mirrour, after Reflection, they will meet before the Glass, at the distance of half a Semidiameter of its Concavity, and there burn

any

any Body held in that Place, which is call'd the *Focus of Parallel Rays*; or simply the Focus of the Glaſs.

15. Hence it follows, that if an Object be held in the Focus of the Glaſs, its Rays, after Reflection, will go parallel, and ſo project no Image of the Object: But if the Object be held nearer than the Center of the Convexity of the Glaſs, and not ſo near as its Focus, there will be an Image in the Air, further from the Glaſs than its Center, and bigger than the Object, as may be ſeen by receiving it upon a Sheet of white Paper; but if the Object be held in the Place of the Image, the Image will be projected in the Place where the Object was, and be leſs than the Object, and in both Caſes inverted, becauſe the Rays croſs at the Center of the Glaſs.

16. A Poliſh'd Cylinder will make a Picture, optically deform'd, to appear in true Proportion, when ſeen by Reflection from it. *The Picture is made only upon this Principle, that the Angle of Incidence is equal to that of Reflection.*

A ſhort Candle ſtanding in a hollow Poliſh'd Cylinder; will appear rais'd up by Reflection, upon the above-ſaid Principle.

17. A Convex Lens reflects two Images; an erect one from the Convex Surface towards you, and an Inverted one from the Surface on the other ſide; becauſe it is concave towards you.

18. The Reaſon why a Picture is a Repreſentation of an Object, is, becauſe the Paint is laid on in ſuch manner, that the Light which falls upon it, will after Reflection enter the Eye, juſt as if it was reflected from the real Objects, ſuppos'd behind the Picture, imagin'd to be tranſparent.

LEC-

LECTURE XVII.

1. WHEN a Ray of Light goes out of one Medium into another, so as to come obliquely against the Surface of the Second Medium, it is at its entrance into it, turn'd out of its way, so as to go on in another right Line, than that in which it mov'd before. —— And this is call'd the *Refraction* of a Ray of Light.

2. If a Ray of Light goes out of a rare Medium into a denser, it is *refracted towards the Perpendicular*; if from a dense into a rare Medium, it is *refracted from the Perpendicular*.

The Physical Cause of the Refraction, is the Greater or Less Attraction of the new Medium; as for Example, when the Refraction is made towards the Perpendicular, in the Case of a Ray of Light going obliquely out of Air into Glass, just as the Ray enters the Glass, it is acted upon by two Forces, *viz.* The Motion that it has already in the Direction with which it comes upon the Glass, and the Attraction of the Glass, which acts upon it, along a Perpendicular, to the Surface of the Glass at the Point of Incidence; and therefore, by the Laws of Mechanics, that Ray must move in the Diagonal of the Parallelogram, whose Sides represent those two Forces, which consequently is nearer the Perpendicular: And as that Diagonal is described in the same time, as either of the Sides wou'd be describ'd by either of the Forces alone, a Ray of light moves faster in a dense Medium, than in a rare, in the same proportion that the Angle of Refraction is less than the Angle of Incidence. On the contrary, when a Ray of Light comes out of a denser Medium into a rare,

rare, as out of a Glaſs into Air, it is retarded as it comes out of the Glaſs, becauſe the Attraction of the Glaſs draws counter to the direction of the Ray, and ſo both turns it from the Perpendicular, and retards its Motion. When the Object and its Image are of equal bigneſs, they are alſo equally diſtant from the Lens, the Diſtance of each being equal to twice the Glaſs's focal Diſtance.

From hence it follows, that Light muſt paſs more eaſily thro' tranſparent Bodies, than thro' a Vacuum.

3. An Inſtance of the Attraction of the Glaſs influencing the Ray of Light, may be ſeen in the following Experiment. Hold one of the Surfaces of a Priſm in an Horizontal Poſition, with the Angle oppoſite to it upward, and looking very obliquely at it, the Light of a Candle ſeen by Reflection, will ſtrike the Eye very vividly, ſeeming to be reflected from the Air contiguous to the Glaſs; tho' the true Reaſon is, that the Rays of Light which come out under the Priſm, make ſo ſmall an Angle with the Plane of Emerſion, that the Attraction of the Glaſs makes the Rays deſcribe a Curve, and reenter the Glaſs, ſo as to fall upon the Eye, after this Reflection from an imaginary Surface very near to that of the Priſm. If the Incident Rays make a great Angle with this Plane, only the moſt refrangible, or blewiſh Rays, will be reflected, or brought back up again to the Eye, the others at their Emerſion from the under part of the Glaſs, making too great an Angle for the Attraction of the Glaſs to turn them up again into its Body. If you take another Priſm, and preſs one of its Planes againſt the lower Plane of the Priſm above-mention'd, the Light will no longer be reflected by the lower Surface of the firſt Priſm; but being attracted by the Second, paſs thro' it, and that only in the Place where the

two

two Prisms touch, because that kind of Attraction is insensible, unless at a very small distance.

4. The Experiment of the Piece of Money, which in the Bason of Water appear'd about one fourth part higher than it was, shew'd what Refraction is, and that out of Water into Air, the Refraction is made from the Perpendicular.

5. It appear'd by Experiment, that when Light passes obliquely thro' Plates of Glass, whose Surfaces are parallel, the Refraction of the Ray of Light going into the Glass, is so taken off by the Refraction of the Ray going out of the Glass, that the Object seems not out of its Place, when view'd obliquely thro' such a Plate, when its thickness is inconsiderable, as in common Window-Glass; but it appears a little remov'd, tho' not alter'd in Shape, when the Plate of Glass is of a considerable thickness.

6. An Object view'd thro' a Piece of Glass, whose Surfaces are not parallel, is never seen in its true place, as appear'd by the Prism, which makes the Objects appear considerably higher or lower than they are, according as the refracting Angle of the Prism is held, upwards or downwards.

The Colours seen thro' the Prism, are owing to the different refrangibility of the Rays, which will be explain'd in another Lecture.

7. A *Multiplying-Glass* shews the Object in several Places at once, by reason of the different Inclination of the several plane Surfaces on one side of the Glass, to the single flat Surface which makes the other Side, none being parallel to it, but the Middle one, thro' which the Object always appears in its proper Place. The Object is multiplied in proportion to the Number of the Planes, and the Eye must be plac'd where the Rays of Light which come from the Object meet by the Refraction of the several

ſeveral Planes, after they have paſs'd the Glaſs. That Point may be call'd the *Focus of the Multiplying-Glaſs*; and if the Object be but one lucid Point, the Rays from the Object to the Glaſs, and from the Glaſs to the Eye, will be a Pencil of Rays.

8. If we look upon a *Plano-Convex Lens*, as a Multiplying-Glaſs, whoſe Convexity is made up of an infinite Number of infinitely ſmall Flats, a Candle ſeen thro' it muſt appear in an infinite Number of Places; that is, muſt fill the whole Glaſs, which is juſt the Caſe when you look at the Candle, from the Focus of the Rays, which meet on the other ſide of the Glaſs. A double Convex Lens, may be thus compar'd to a double Multiplying-Glaſs.

9. If an Object be at a vaſt diſtance from a Convex Lens, or a diſtance very great in proportion to the Radius of the Convexity of the Glaſs, the Image of that Object will be projected in the Focus of the Glaſs, which is call'd its *Focus of Parallel Rays*. If the Glaſs be expoſed to the Sun's Rays, it will unite them at the ſaid Focus, and burn any Object held in it. On the contrary, if a Radiant be held in the Glaſs's Focus, the Rays (after Refraction) will project no Image of the Object, but go on parallel; if the Radiant be held nearer to the Glaſs, the Rays after paſſing the Glaſs will diverge, tho' not ſo much as they did before they enter'd the Glaſs: The Focus of ſuch Rays, therefore will be found, by producing them back again to a Point before the Glaſs where they will meet, which will be farther from the Glaſs than the Radiant; an Eye therefore to ſee this Image in the above-ſaid Focus, muſt be on the other ſide of the Glaſs. N. B. *Hence may be known the Reaſon why an Object ſeen thro' a Convex Lens, held nearer it than its Focus of parallel Rays, appears farther from the Glaſs than it is.*

10. If the Object be held farther from the Lens than its Focus of Parallel Rays, it will project an inverted Image of it self on the other side of the Glass, with this Rule —— That, the nearer the Object is to the Glass, the farther is its Image behind it, and the bigger; the farther the Object, the nearer the Image, and the less. *When the Object and its Image are of equal bigness, they are also equally distant from the Lens; the Distance of each being twice the Glass's focal Distance.*

LECTURE XVIII.

1. WHEN by means of a Convex Lens, the Image of the Candle, or any other Object is projected, each Point of the Object is represented in the Image, by means of a Pencil of Rays proceeding from that Point. The *Axis* of the Pencil is the middle Ray of the Pencil, which passing thro' the middle of the Glass, is unrefracted, or not sensibly refracted. Hence it happens, that the Rays which proceed from the top of the Candle, or any other Radiant, and fall diverging upon the Lens, will be united again on the other side of it, upon their Axis at the bottom of the Image: Likewise the lower Point of the Object will (by means of the Pencil of Rays from it) be represented in the upper part of the Image; and so of all the other Points, according as they are above or below the middle of the Object. This is the Reason why the Images of erect Objects are inverted.

2. If a Room, whose Window looks towards Objects enlighten'd by the Sun, be darken'd all but one Hole, in which you fix a double Convex Lens; you

you may in the Focus of that Lens, receive upon a white Sheet very lively Images of the external Objects in their proper Colours, but inverted.

A Box made in the manner of ſuch a Room, is call'd the Portable *Camera obſcura*; with this difference only, that, (by means of a reflecting plane Looking-Glaſs, fix'd at an Angle of 45 Degrees, with the Axis of the Lens) the Objects are painted erect, upon a rough flat Glaſs laid Horizontally over the End of the Box, ſo as to receive the Rays that have paſs'd thro' the Lens by Reflection.

3. The Eye is like the dark Chamber, the Pupil being as the Hole in the Window ſhut, the Humours of the Eye as the Lens in the Hole, and the Retina as the Sheet of Paper, held in the Focus of the Glaſs, which receives the inverted Images of erect Objects. To prove this, cut an Hole in the back part of a freſh Sheep's Eye, taking away all the other Coats, and leaving only the Retina in the Hole, ſo that the Vitreous Humour be not bruis'd; then holding a Candle before the forepart of the Eye, you will ſee the inverted Image of the Candle upon the Retina in the back part of the Eye, beheld thro' the Hole.

Here follows a ſhort Deſcription of the Eye.

1. THE Coat which encloſes the whole Eye, is call'd the *Sclerotica*, from its Hardneſs, whoſe forepart being tranſparent like Horn, is call'd the *Cornea*: Under the *Cornea*, is the *Aqueous* or Watry Humour. The Coat that immediately lines the *Sclerotica*, is call'd the *Choroides*, one part of which of a whitiſh Green, is call'd the *Uvea*: This Coat, when it is come to the *Cornea*, is doubled to make the *Iris* of the Eye, whoſe Colour gives Colour to the Eye: The Hole of the Iris, call'd the *Pupil*, may be contracted or dilated; that the Eye may not receive too much Light, from a very bright, or a

very near Object; or too little Light, from a distant, or too dark Object; The Iris having the aqueous Humour both before and behind it, is said to swim in it. Next is the *Chrystalline* Humour, shap'd like a Convex Lens of Glass, inclos'd in a very thin Membrane, call'd the *Aranea*, whose Circumference is fix'd to the *Ligamentum ciliare*, (a black Ligament made of the black Threads of the Choroides, lying like Radii, that tend to the Center of the Chrystalline) which serves to bring backward and forward the Chrystalline, or as some say, to make it more or less flat, in order to render the Eye more or less convex, according as we look at a nearer or more distant Object. Beyond the Chrystalline, is the *Vitreous* Humour, which fills up all the rest of the Eye: Its weight is six times more than the Chrystalline, and twelve times more than the Aqueous Humour. The *Retina*, which encloses all this Humour, lining the Eye as far as the *Ligamentum ciliare*, is the Part on which Vision is perform'd; that is, it receives the Images of external Objects, by means of the Rays, which coming from every Point of the Object, are by the Refraction of these Humours, (whose Figures are given by their Coats) brought to meet in correspondent Points of the Retina; every Pencil of Rays, by which we see Objects, having one Cone without the Eye, and the other Cone within it.

The Retina is made of the Threads of the Optic Nerves, which passes quite thro' the *Sclerotica* and *Choroides*; and receiving the Impulse of the united Rays, that strike it so as to give Vibrations to the several Nervous Fibres, carries the Sensation to the common *Sensorium*, where (by Means yet unknown to us) the Soul is affected with it.

2. If the Eye was not made of flexible Coats, and yielding Humours, we shou'd be able to see no Objects

jects distinctly, but such as are at one certain distance from the Eye; for the Rays from a too distant Object, wou'd have their Focus (or come to a Point) in the Eye short of the Retina; and the Rays from a too near Object, wou'd be intercepted by the Retina, before they came to a Point; but when the Object is near, the *Ligamentum ciliare* pulling forward the Chrystalline, presses the Aqueous Humour hard against the Cornea, so as to render it more Convex, and by that means make those Rays which wou'd have had their Focus beyond the Retina, to unite upon it; and when the Object is distant, the same Ligament pulling back the Chrystalline, causes the Eye to become flatter, and so makes those Rays to unite upon the Retina, whose Focus before was short of it.

3. An Eye naturally too convex to flatten it self enough for the distinct beholding of distant Objects, is a Short-sighted Eye; and an Eye too flat to be made convex enough for the distant Vision of near Objects, is an old Eye. Those that have the former defect, are call'd *Myopes*, and such as have the latter *Presbytæ*.

To illustrate this farther, the following Experiments are made.

4. Holding a Convex Lens between a Candle and a white Paper so as to project a distinct Image of the Candle upon it, let the Candle be remov'd a little farther, and the Image will no longer be distinct upon the Paper, unless you bring it nearer; but if keeping the Paper at the first distance, you make use of a Lens, which is not so convex as the former, you will project upon the Paper a distinct Image of the now more distant Candle: This shews the Reason, why the Eye is flatten'd when we look at distant Objects. If the Candle be brought nearer to the Glass, the Image will also be indistinct upon

the Paper, 'till you substitute a more Convex Lens, whose shorter Focus will just fall upon the Paper, and so render the Image cast upon it very distinct; so the Eye is made more convex to look at near Objects. But if the Candle be brought so near the Glass as is its Focal Distance, or nearer, the Rays after passing the Glass will go on parallel or diverging, and so project no Image of the Candle upon the Paper; which shews, that there is a distance from the Eye, which is too near for distinct Vision, namely, any distance shorter than the Eye's focal distance: And if a Candle be at a vast distance, its Image projected upon the Paper will be extreamly small; so when we look at a very distant Object, its Image is so small upon the *Retina*, that unless it be a very bright Object, we can hardly perceive it.

LECTURE XIX.

1. A Well-made Eye unites *Parallel Rays* (or Rays which come from a Point at a great Distance) upon its Retina; but an old Eye must have the Rays converge a little, when they fall upon its Cornea, and a short-sighted Eye must receive them diverging, in order to have them come to a Point upon the Retina.

2. When therefore an old Eye brings a small Object (as *Writing* in a Book) near enough to have a large Image upon the Retina; the Rays in that case diverging, will have their Focus beyond the Retina; because the old Eye cannot make it self convex enough; but by applying a convex Lens, or Spectacle before it, the diverging Rays, after their Refraction

thro'

thro' the Glaſs, will be made to converge as they enter the Cornea, and ſo unite in Points upon the Retina, correſpondent to thoſe Points of the Object from whence they come, and by that means reſtore the diſtinct Viſion which was loſt by the too near approach of the Object.

3. When a diſtant Object cannot be brought near enough to a ſhort-ſighted Eye, (which cannot make it ſelf flat enough) then a Concave Lens muſt be held before it, which will make the Parallel Rays diverge before they come upon the Cornea: Then thoſe Rays which wou'd have had their Focus ſhort of the Retina, will unite upon it, and make the Eye thus arm'd, ſee the Object with the ſame diſtinctneſs as if it was brought nearer.

To Illuſtrate this farther, take a convex Lens, and project the Image of a diſtant Candle upon a Paper, as has been before mention'd, then having remov'd the Paper back, 'till the Image is confus'd, (as it happens in the too diſtant Retina of a ſhort-ſighted Eye, looking at a diſtant Object) apply a Concave Lens before the Convex one, and the Image of the Candle will fall diſtinctly upon the Paper.

4. If the Candle be brought ſo near the Convex Lens, as to throw its Image beyond the Paper; you may by applying a Spectacle, or another Convex Lens before it, bring the Image which was confus'd upon the Paper, to become diſtinct; juſt in the manner that old Eyes are help'd.

5. When parallel Rays fall upon a Plano-Concave, or a Double concave Lens, their Refraction in paſſing thro' the Glaſs, will make them go afterwards diverging; but if you produce thoſe Rays back to that Side of the Glaſs, from whence they came, they will unite there in a Point call'd the *Focus*, or *virtual Focus of the concave Lens.*

If

If a Short-Sighted Eye can ſee diſtinctly but at the Diſtance of five Inches, then it will be able to ſee diſtant Objects by help of a Concave Lens, whoſe virtual Focus is at five Inches from the Glaſs.

6. When a Lens is but little convex, or concave, ſo as to have its Focus at a great diſtance, and to appear flat to the Touch, the way to know whether it be Ground Convex, or Concave, is to look full upon any Object, holding the Glaſs between your Eye and the Object: Then if by ſhaking the Glaſs, the Object appears to dance, the Glaſs is a *Lens*, (or a Glaſs which is convex or concave) becauſe the Rays fall with a different Inclination upon different parts of the Glaſs; but no ſuch dancing will happen if the Glaſs be quite flat.

7. There are ſeveral Ways of finding the Focus of a Lens, of which the two beſt are as follow. —— Hold a Lens to the Sun, and the Focus will be where the Sun's Rays unite and burn; or elſe put the Lens into the Hole of a dark Room, and obſerve the diſtance, where a Paper held will receive the diſtinct Image of diſtant Objects, and that will be the focal Diſtance.

8. If a convex Lens has its thickeſt part in the Middle, it is ſaid to be *truly Center'd*, and a Line paſſing thro' that thicker Part, and the Foci of the Glaſs on each ſide, is call'd *the Axis of the Glaſs.* Now as in Glaſſes of long Foci, one cannot ſee where the Glaſs is thickeſt, the following Experiment will determine whether the Glaſs be truly center'd. —— Hold the Lens to the Sun, and throwing the Sun's Light by Reflection againſt ſome dark Body, you will ſee a large white Circle, and a ſmall white circular Spot within it, brighter than the other. If the bright Spot be juſt in the Middle of the other, the Glaſs is truly center'd, otherwiſe not.

9. If

9. If from the two Ends of the Object, be drawn Lines to the Middle of the Pupil of the Eye, (which are the Axes of the Pencils from each end of the Object) the Angle which thoſe two Lines make at the Eye, is the *Viſual Angle*, or the Angle *under which* Objects are ſaid to be ſeen. An Object appears large or ſmall, according to the Angle under which it is ſeen; becauſe thoſe Rays or Lines which make the above-ſaid Angle, after their croſſing, go to the Retina of the Eye, where they determine the Magnitude of the Image upon the Retina. Hence, if an Object that was at two Foot from the Eye, be brought to the diſtance of one Foot, it will be ſeen under an Angle, twice as big, and appear to have a Diameter as big again; the Image of it upon the Retina being twice larger than before.

For this Reaſon, when an Object is very ſmall, it muſt be brought nearer the Eye, in order to ſee it under a great Angle: But if to make it appear large enough, it be brought very near the Eye, the Rays will diverge ſo much from every Point of it, as to have their Focus beyond the Retina, ſo that a very convex Lens muſt be interpos'd between the Object and the Eye, to correct the divergence of thoſe Rays, in the ſame manner that a Spectacle helps an old Eye; then the Image will be diſtinct upon the Retina, without being diminiſh'd. Such a Lens is the *Single Microſcope*, and the more convex it is, the more is the Object magnified by means of it; as being allow'd to be brought very near, when the Lens is made of Segments of a ſmall Sphere, or is it ſelf a little ſpherule of Glaſs, ſome of which are ſo ſmall, as to need another Microſcope to ſee them.

10. To know how much a Microſcope magnifies, take a round piece of Paper, and ſticking it to a Pane of Glaſs, look with one Eye at the ſaid Paper,

If a Short-Sighted Eye can ſee diſtinctly but at the Diſtance of five Inches, then it will be able to ſee diſtant Objects by help of a Concave Lens, whoſe virtual Focus is at five Inches from the Glaſs.

6. When a Lens is but little convex, or concave, ſo as to have its Focus at a great diſtance, and to appear flat to the Touch, the way to know whether it be Ground Convex, or Concave, is to look full upon any Object, holding the Glaſs between your Eye and the Object: Then if by ſhaking the Glaſs, the Object appears to dance, the Glaſs is a *Lens*, (or a Glaſs which is convex or concave) becauſe the Rays fall with a different Inclination upon different parts of the Glaſs; but no ſuch dancing will happen if the Glaſs be quite flat.

7. There are ſeveral Ways of finding the Focus of a Lens, of which the two beſt are as follow. —— Hold a Lens to the Sun, and the Focus will be where the Sun's Rays unite and burn; or elſe put the Lens into the Hole of a dark Room, and obſerve the diſtance, where a Paper held will receive the diſtinct Image of diſtant Objects, and that will be the focal Diſtance.

8. If a convex Lens has its thickeſt part in the Middle, it is ſaid to be *truly Center'd*, and a Line paſſing thro' that thicker Part, and the Foci of the Glaſs on each ſide, is call'd *the Axis of the Glaſs*. Now as in Glaſſes of long Foci, one cannot ſee where the Glaſs is thickeſt, the following Experiment will determine whether the Glaſs be truly center'd. —— Hold the Lens to the Sun, and throwing the Sun's Light by Reflection againſt ſome dark Body, you will ſee a large white Circle, and a ſmall white circular Spot within it, brighter than the other. If the bright Spot be juſt in the Middle of the other, the Glaſs is truly center'd, otherwiſe not.

9. If from the two Ends of the Object, be drawn Lines to the Middle of the Pupil of the Eye, (which are the Axes of the Pencils from each end of the Object) the Angle which those two Lines make at the Eye, is the *Visual Angle*, or the Angle *under which* Objects are said to be seen. An Object appears large or small, according to the Angle under which it is seen; because those Rays or Lines which make the above-said Angle, after their crossing, go to the Retina of the Eye, where they determine the Magnitude of the Image upon the Retina. Hence, if an Object that was at two Foot from the Eye, be brought to the distance of one Foot, it will be seen under an Angle, twice as big, and appear to have a Diameter as big again; the Image of it upon the Retina being twice larger than before.

For this Reason, when an Object is very small, it must be brought nearer the Eye, in order to see it under a great Angle: But if to make it appear large enough, it be brought very near the Eye, the Rays will diverge so much from every Point of it, as to have their Focus beyond the Retina, so that a very convex Lens must be interpos'd between the Object and the Eye, to correct the divergence of those Rays, in the same manner that a Spectacle helps an old Eye; then the Image will be distinct upon the Retina, without being diminish'd. Such a Lens is the *Single Microscope*, and the more convex it is, the more is the Object magnified by means of it; as being allow'd to be brought very near, when the Lens is made of Segments of a small Sphere, or is it self a little spherule of Glass, some of which are so small, as to need another Microscope to see them.

10. To know how much a Microscope magnifies, take a round piece of Paper, and sticking it to a Pane of Glass, look with one Eye at the said Paper,

and with the other at the Object in the Microscope, 'till you see the Object in the Microscope seem just as big as the Paper on the Glass; then, *As the Distance of the Paper from the Eye, is to the Distance of the Object from the Lens of the Microscope; so is the apparent Diameter of the Object seen by the Microscope, to the apparent Diameter of it seen by the naked Eye;* or in other Words ——The Object, or the Part of it seen by the Microscope, is magnified in proportion to the Difference of the above-said distances.

11. If you prick a small Hole in a Card, and thro' it look at a small Object brought nearer to the Eye than the Limits of distinct Vision do allow of, you will see it magnified as you wou'd by means of a small Microscope; but it will appear dark. The Reason of it is, that tho' the Rays from every Point of such an Object diverge too much when they fill the whole Pupil, yet the Card suffers only such of them to pass as are very near the Axis of each Pencil, which diverge but just enough to have their Focus upon the Retina; but the Rays that pass thro' such an Hole are so few, that the Object appears dark, and therefore such a Microscope is of little use.

N. B. When we look at a near Object, we contract our Pupil, as well not to take in the too divergent Rays, as not to take in too much Light: This contrivance of the Card is no other, than a farther contraction of the Pupil.

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LECTURE XX.

1. A *Compound Microſcope* is commonly uſed to look at opaque Objects, as the Single one is chiefly us'd to look at tranſparent ones: The double one takes in a great deal of an Object at a time, which it ſees inverted, and ſeldom magnifies ſo much as a good ſingle one. The Deſcription of it is as follows. —— The ſmall Object to be view'd, being expos'd to a ſmall Lens of a deep convexity at a diſtance ſomething greater than its focal diſtance; but not ſo great at twice that diſtance, projects a large inverted Image of it ſelf on the other ſide of the Glaſs; which magnified Image the Eye looks at with another convex Lens, or ſometimes two of them together, (which take in more than a ſingle one, becauſe they are broader than a ſingle one that will make the Rays converge as much as both of them combin'd) ſo as to ſee this Image magnified, or under a great Angle, the Eye-Glaſſes allowing the Eye to be brought pretty near the ſaid Image, which in this Caſe is view'd in the ſame manner, as if it was the principal Radiant or Object. We are to obſerve, that the Eye in the Focus of the Eye-Glaſs, ſees the projected Image (and wou'd ſee an Object) under the ſame Angle as if it was in the Place of the Eye-Glaſs; but as it wou'd ſee it confuſedly, tho' large in that Place, we are oblig'd to uſe an Eye-Glaſs, in order to recover diſtinct Viſion, as in the caſe of a ſingle Microſcope: And as a well made Eye unites upon its Retina ſuch Parcels of Rays as are parallel to each other when they enter the Cornea, the Eye-Glaſs for ſuch an Eye to make uſe of, muſt be placed at its focal diſtance from the

Image projected by the Object-Glass, that the Rays diverging from every Point of the Image, may after passing the Eye-Glass, be parallel to their respective Axes: Now as the Angle made at the Eye by the Axes of the Pencils of Rays coming from each end of the Object, is the Angle under which we see it, the Eye must be in the *Focus of those Axes*, (and indeed the *common Focus of the Axes of all the Pencils*) which will be something farther from the Eye-Glass than its Focus of parallel Rays, because those Axes are a little diverging when they fall upon it; for when they come from the principal Radiant, they cross'd at the Object-Lens, from which point of crossing they diverge to fall upon the Eye-Glass, not being turn'd out of their direction 'till they come to it, tho' the Image is projected between the Object-Glass and the Eye-Glass. If therefore we wou'd know in what direction the Rays enter the Eye in this Case, we shall find both a Parallelism and a Convergency. The Rays belonging to each Pencil, which comes from each Point of the Object are Parallel to their respective Axes, and therefore (being refracted in passing thro' the Humours of the Eye, so as to unite upon correspondent Points of the Retina) give distinct Vision; but all the Pencils coming each from a different Point of the Object, after passing the last Eye-Glass, converge at the Pupil of the Eye, and by the Angle which their respective Axes make, give the apparent distance of every Point of the Object from each other, and consequently the apparent Magnitude of it.

2. As the Microscope is of use to look at Objects so small, that they project too little an Image of themselves, when they are not too near the Eye to be out of the Limits of distinct Vision: So the *Telescope* serves to enlarge the Angle under which a distant Object (which we cannot approach to) is seen; and that

that is done with a convex Object-Glaſs, and one or more convex Eye-Glaſſes, as in the Microſcope, only with this difference, that the Object-Glaſs is leſs convex than the Eye-Glaſs, whereas in the Microſcope it is more Convex.

There is indeed a Teleſcope invented by *Galilæo*, whoſe Eye-Glaſs is concave; but we ſhall firſt deſcribe the *Aſtronomic Teleſcope*, (ſo call'd from its being now chiefly us'd to look at Celeſtial Bodies) which conſiſts only of two convex Glaſſes.

3. We have ſhewn before, that the flatter a convex Lens was, the more diſtant was its Focus, or diſtinct Baſe in which it projects the Image of diſtant Objects; we have alſo made it appear, that the farther the Image was projected on the other ſide of a convex Lens, the larger it wou'd be. Now as we cannot bring the Object near the Lens, to project a large Image of it by that means, we muſt make uſe of a Lens of a ſmall Convexity, (or a Segment of a large Sphere) which for the above-ſaid Reaſons will project a large inverted Image of the Object in its Focus, which Image is beheld by the Eye, arm'd with an Eye-Glaſs of a ſhort Focus, and ſeen under the Angle, which two Lines from the Extremity of the Image, make at the Eye-Lens.

4. The uſe of the Eye-Glaſs is the ſame as in the double Microſcope; but care muſt be taken here as well as there, that the Eye-Glaſs be not too convex in proportion to the Object-Glaſs; becauſe the Object wou'd then appear coloured. The longeſt Object-Glaſſes (or thoſe of the greateſt focal diſtance) require the longeſt Eye-Glaſſes; but of two Object Glaſſes of the ſame convexity, the beſt will bear the *greateſt Charge*, or ſhorteſt Eye-Glaſs.

5. A Short-Sighted Man may uſe a Teleſcope without an Eye-Glaſs, except it be a Teleſcope ſo ſhort, that the Focal diſtance of its Eye-Glaſs is

much

much ſhorter than the Diſtance at which the Short-Sighted-Man ſees diſtinctly. As for Example, If ſuch a Man ſees diſtinctly at the diſtance of four Inches, he may uſe a Teleſcope (whoſe Eye-Glaſs is of four Inches Focus) without the Eye-Glaſs; becauſe then the Rays from every Point of the Image to his Eye will diverge no more than they wou'd from an Object at that diſtance; and he ſhall ſee the Object magnified as much as others that uſe the Eye-Glaſs, becauſe he ſees it under the ſame Angle. If the Focal diſtance of the Eye-Glaſs be greater than the Short-Sighted-Man's diſtance of diſtinct Viſion, he ſhall ſee the Object more magnified than when it is ſeen with the above-ſaid Eye-Glaſs: But if the focal Diſtance of the Eye-Glaſs be ſhorter than the Short-Sighted-Man's diſtance of diſtinct Viſion, he will not ſee the Object ſo much magnified without the Eye-Glaſs, as with it; becauſe his Eye is not convex enough to be brought as near the Image as the Eye-Glaſs was, without loſing diſtinct Viſion.

6. The difference between a Short Sighted-Man uſing a Teleſcope without an Eye-Glaſs, and another uſing an Eye-Glaſs equivalent to the too great Convexity of the Short-Sighted-Man's Eye, is, that a great deal more may be taken in with the Eye-Glaſs, than without it, and that in ſome proportion of the Bigneſs of the Eye-Glaſs to the bigneſs of the Pupil; beſides it will be difficult to uſe a Micrometer without an Eye-Glaſs; but then on the other hand, a ſhort-ſighted Eye will ſee much more diſtinctly than one can with an Eye-Glaſs, and can take in all the Parts of the Object ſucceſſively.

This way of applying a Teleſcope to a Short-Sighted-Eye, I found very uſeful in looking at Saturn's Ring; and in making the Experiment, I was able to take in an Angle of about ſix Minutes with a fifteen Foot Teleſcope, and I ſaw the Satellites of Jupiter very plain with a two Foot Object-Glaſs.

7. The

7. The above-mention'd Aſtronomic Teleſcope inverting the Objects, (which is no inconveniency in looking at Spherical Bodies, ſuch as the Celeſtial ones, eſpecially when we have the Advantage of ſeeing them thro' a ſmall thickneſs of Glaſs) two Glaſſes more are apply'd, when we look at Objects upon Earth, where by an erect Image of the Firſt inverted one is projected between theſe two laſt Eye-Glaſſes; ſo that the Eye arm'd with the third Eye-Glaſs, ſees an erect Image of an inverted Image of the erect Object; and conſequently the Image on the Retina is inverted, and therefore the Object appears erect. One Glaſs might do inſtead of the two laſt; that is, two Eye-Glaſſes and the Object-Glaſs might ſhew the Object erect; but there wou'd be wanting the conveniency of fitting all Eyes, by only thruſting in, or pulling out the Drawer in which the Three Eye-Glaſſes are fix'd, and always keep the ſame diſtance from each other, with the ſame diſtinctneſs; but when the three Eye-Glaſſes are thruſt a little nearer to the Object-Glaſs for a Short-Sighted-Eye, the Rays of each Pencil will diverge from their Axis, juſt in the ſame manner, as if a ſingle Eye-Glaſs had been put a little nearer to the Focus of the Object-Glaſs than its focal Diſtance: Likewiſe, if the ſaid three Glaſſes be drawn out farther from the Object-Glaſs, to fit an old Eye, the Rays of each Pencil will converge towards their Axis, in the ſame manner, as if the ſingle-Glaſs was drawn out a little in the Aſtronomic Teleſcope. Now if there were only two Eye-Glaſſes, not only the diſtance of both from the Object-Glaſs, but their diſtance from each other alſo muſt be alter'd for different Sights, or very little of the Object wou'd be taken in.

8. *Galilæo*'s *Teleſcope* is made of a Convex Object-Glaſs, and concave Eye-Glaſs, combin'd in the following manner. Take a concave Lens, whoſe virtual Fo-

cus-

cus (*described in Lecture* 19.) is as much ſhorter than the Focus of the Object-Glaſs, as you wou'd have the Object magnified, and fix it ſo much nearer to the Object-Glaſs than its Focus, that the Focus of the Object-Glaſs may fall beyond the Eye-Glaſs, juſt at the virtual Focus of the Eye-Glaſs. Then the Eye being apply'd juſt behind the concave Glaſs, will receive thoſe Rays parallel to each other, which otherwiſe wou'd have converg'd. This Teleſcope magnifies much; but it takes in but a little, and cannot be of uſe for a Micrometer, becauſe by it we do not look at the Image of the Object, but at the Object it ſelf; whereas in the Aſtronomic Teleſcope, the Image of the Object being projected in the common Focus of the Object-Glaſs, and Eye-Glaſs, a Micrometer or croſs Hairs in that place, appear to be upon the Object it ſelf.

I have found old Eyes ſo flat, as to be able to make uſe of Galilæo'*s Teleſcope without an Eye-Glaſs, where the Concavity of it is but ſmall.*

9. As the Focal diſtance of the Object-Glaſs to the Focal Diſtance of the Eye-Glaſs; ſo is the apparent Diameter of an Object ſeen thro' a Teleſcope, to the apparent Diameter of the Object ſeen with the naked Eye.

This Proportion will hold as well in Galilæo'*s Teleſcope, as in the Aſtronomic Teleſcope.*

LEC-

LECTURE XXI.

1. IF we ſuppoſe a Line drawn thro' the middle of the Eye, ſo as to paſs thro' the Centers of all the Coats and Humours of the Eye; ſuch a Line is call'd the *Optic Axis.*

2. When we look full at any Point of an Object, we make the *Optic Axes* of both Eyes meet at that Point of the Object, and always ſee that Point ſingle. But whilſt we are looking at that Point, other Objects that are not directly before us do paint themſelves alſo upon the *Retina*: Such Objects we *ſee* without *looking* at them; and if they happen to be either beyond this Point where the *Optic Axes* meet, or ſhort of it, they will appear double: And therefore the difference between *Looking* and *Seeing* is this; that when we *Look* at an Object, we always ſee it plaineſt and ſingle, but when we *ſee* an Object without looking at it, it always appears duller, and ſometimes double.

3. This appear'd by the Experiment upon two Candles in a Line; for looking at the neareſt, the fartheſt appear'd double; and looking at the fartheſt, the neareſt appear'd double.

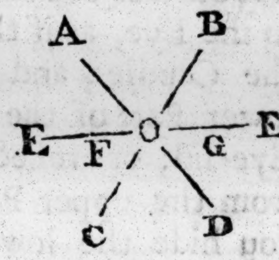
The reaſon of this Phænomenon is, that when one Candle paints its Image upon the middle of the *Retina* in each Eye, the Fibres of the middle of the *Retina* of each Eye joyn together in the Head where the Optic Nerves meet, before they come to the Brain or common *Senſorium*, and ſo give but the Senſation of one Image; but when the other Candle (ſuppoſe it nearer) paints its Image upon the

Retina of each Eye farther from the Noſe than the middle of the Eye, the Fibres of the exterior Part of the *Retina* of one Eye, not communicating with the Fibres of the exterior Part of the *Retina* of the other Eye, we have the Senſation of two Images: Likewiſe there being no Communication between the interior Parts of the *Retina* of each Eye (where the Images are painted; when the Candle *ſeen* is beyond the Candle *look'd at*) we ſhall then alſo have a Senſation of two Images.

4. That the Fibres on the right Hand ſide of the *Retina* of the right Eye, communicate with their correſpondent Fibres on the right Hand ſide of the *Retina* of the left Eye; and thoſe on the left in one Eye with thoſe on the left in the other —— was ſhewn by the Experiment of the two Candles (each equally diſtant from each Eye, with a vertical Plane betwixt them) which appear'd but as one, when they were ſeen without being look'd at; for then each projecting an Image of it ſelf reſpectively on the left Part of the *Retina* of each Eye, and thoſe Images being ſimilar and equal (becauſe the Candles were of the ſame bigneſs and height, and at the ſame diſtance from the Eyes, each from each) the correſponding Fibres which receive them by communicating together, repreſent them to the common *Senſorium*, as Images from one Object, or as one Image in one Eye.

Upon theſe Principles it was, that the Two Candles (in another Experiment, where they either were *look'd at*, or *ſeen* thro' an Hole in a Board held before them) appear'd ſingle, when the Hole was *look'd at*; and double, with the Hole alſo double, when they were *ſeen* by looking at thoſe Parts of the Board that were againſt the Candles. For if *A* and *B* are the two Candles, and *O* the Hole in the

the Board, when the Eyes at *C* and *D* are so turn'd as to have their Axes meet at *O*, the Candle *A* paints it self in the middle of the *Retina* of the Eye at *D*, and the Candle *B* in the middle of the *Retina* of the Eye at *C*, just as one Candle at *O* would do;



but if the *Optic Axes* are turn'd to the Points of the solid Board at *F* and *G*, the Candle *A* together with the Hole will paint it self on the exterior, or right Part of the *Retina* of the Eye at *D*; and the Candle at *B* together with the Hole will paint it self on the exterior or left Part of the Eye at *C*, and therefore these Images not communicating, you will for the Reasons above given see two Holes and two Candles.

5. The Reason why some People see double when they are drunk, is, that thro' the hurry of their Blood and Spirits they have a trembling in the Muscles of the Eye, and so cannot direct both their *Optic Axes* to one Point; but if they shut one Eye they will not see double.

6. If we look at a Candle with one or both Eyes almost shut, we shall see *Beams of Light* darting upwards and downwards from the Candle, which will vanish when the Eyes are fully open. What is remarkable in this *Phænomenon* is this; that if by bringing up your Finger between your Eye and the Candle, you endeavour to hide the lower Beams or Rays, you will only destroy the upper; and when by bringing down your Finger, you wou'd intercept the upper Beams or Rays, you will only hide the lower. —— To explain this we must consider, that when our Eye-lids are almost close, they are in such a Position, that the Rays which come from the upper Part of the Candle, striking upon the moist or

wet Surface of the lower Eye-lid, will be reflected into the Eye, as if they came from the lower Part of the Candle; and the Rays which come from the lower Part of the Candle, ſtriking upon the upper Eye-lid, are reflected into the Eye, as if they came from the upper Part: When then by your Finger you hide the lower Part of the Candle, the Rays which came to the upper Eye-lid being intercepted, you muſt of Conſequence loſe the upper Beams. The Reaſon why inſtead of Beams above and below, we have not two inverted and one upright Candle, is, that the Eye-lids are but imperfect or irregular *Specula* made up of ſeveral different Surfaces: Juſt as when we endeavour to ſee the Moon by Reflection in Water that has ſmall Waves, we ſhall not ſee the Moon ſingle, but a Row of Moons touching one another, ſo as to make a long Beam of Light.

7. If we invert a drinking Glaſs over a piece of Money in a Plate or Diſh, ſo as to have Water over the piece of Money of the height of about an Inch, we ſhall ſee the piece of Money double, as if one piece was a quarter of an Inch over the other; the lower Piece will appear magnified, but not the upper: So that if the Piece of Money be a Shilling, it will look like a half Crown with a Shilling over it. That the Shilling appears raiſ'd, is owing to the Refraction of the Rays coming from the Shilling, as they emerge out of the plane ſurface of the Water, juſt as in the Experiment of the piece of Money in the Baſon (*Lect.* 2.) for tho' the Rays paſs thro' the drinking Glaſs afterwards, their Direction is not ſenſibly alter'd, becauſe the Concave and Convex Surfaces of the Glaſs are parallel. Thro' the Conic Convex Surface of the Water (to which the Glaſs gives that Figure) the Shilling appears magnified; becauſe the Rays which came from the ſides of the Shil-

Shilling to the Eye, so as to make the Angle under which it must be seen (if there was no Water in the Glass) do decussate or cross before they come to the Eye by their Refraction from the Perpendicular, in coming out of the convex Surface of the Water; and two other Rays from the same Points of the Shilling, but more distant from each other at their Emersion from the Glass, are by the said Refraction brought to the Eye so as to make a larger Angle at it, and shew the Shilling bigger in Proportion to the convexity of the drinking Glass. The larger the drinking Glass the less the Shilling is magnified, and if the Glass was square, so as to have a flat side between the Eye and the Shilling, it would not be sensibly magnified.

7. If you prick an Hole in a black Card, and hold the Point of a Pin betwixt your Eye and the Hole in the Card (all the while looking towards the Candle behind the Card, you will see the Pin magnified and inverted) but dark: And if there be several Holes, you will likewise see the Pin multiplied; this Mr. *Stephen Gray* first observ'd and communicated it to the *Royal Society*, calling it an *Aerial Speculum*.

There is no real Image of the Pin upon the *Retina*, because it is much too near the Eye; but the Rays of Light which come from the lower Part of the Candle, thro' the Hole of the Card, cannot all enter the Eye, because the Point of the Pin is in the way, and therefore the shadow of the Point is cast upon the upper Part of the *Retina*, when the Pin's Point is held upward; and the Rays of Light coming from the upper Part of the Candle thro' the Hole, cast the shadow of the thick part of the Pin upon the lower part of the *Retina*, or do not fall upon the part of the *Retina* which is behind the Pin.

If

If therefore this ſhadow or dark Image upon the *Retina* is erect, it muſt (from what has been ſaid before) make the Object appear inverted.

8. The Rays which come to us from the fix'd Stars, Planets, or any other Celeſtial Phænomenon, which is not in our *Zenith*, (or directly over our Heads) by the Refraction toward the Perpendicular, as they come thro' our Atmoſphere, make the Phænomenon appear higher than really it is. — That the Air does really produce ſuch an Effect, appears from the Experiment of the Object ſeen thro' the Teleſcope and exhauſted Priſm; for the Object appears higher, when the Air is let into the Priſm; and ſtill higher, when the Air is condens'd in the Priſm.

Lecture XXII.

1. LIght conſiſts of *Rays* of different Kinds, which are differently *refrangible* and differently colour'd.

2. When theſe different Rays are all mix'd together, they make *White*, which will never be perfect, without a mixture of all of them in due Proportion. Some of the Experiments made to prove this Truth follow.

3. With a Triangular Glaſs Priſm refract the Sun-Beam, which comes thro' the Hole of the Window of a darken'd Room, and inſtead of only throwing the Circular White Image of the Sun out of its Place, that Image will become oblong, and be chang'd into a *Spectrum* of the following Colours,

lours, *viz.* *Red*, *Orange*, *Yellow*, *Green*, *Blue*, *Purple* and *Violet*. If, by holding the refracting Angle of the Prism downwards, the Image is thrown upwards, the *Red* will be lowest, as being least refracted, the *Orange* next, and so of the rest in order, the *Violet* which it most refracted being highest. If the refracting Angle of the Prism was held upwards, so as to depress the Image, the Colours wou'd be in an inverted Order.

4. If this colour'd Image or *Spectrum* falls upon a convex Lens, the different colour'd Rays will be so united, as to make a Spot perfectly White in their Focus, as will appear by receiving them upon a Paper held in the said Focus: The Spot being colour'd either short of or beyond the Focus; but after meeting they go on in an inverted Order.

5. If you intercept any one of these Colours before they fall upon the Lens, the Union of the rest of the Colours will make but an imperfect White; reddish if the Blue be absent, and bluish if the Red be absent, *&c.* If you intercept them successively, but very quick, the Spot in the Focus will be still perfectly White, because an Impression is made by the last Colour upon the *Retina*, before that which was made by the first be quite extinguish'd. Thus a fir'd Charcoal mov'd circularly very swift, appears like a Circle of Fire.

6. If a piece of red Cloth or Silk, or a red Flower be held successively in the differently colour'd Rays, it will be of that Colour in which it is held, and never appear Red till it be held in the Red Rays; but then the Colour of it will be most vivid; it will be dullest in the Blue, which is the Colour most remov'd in order from the Red. A piece of blue Silk will be successively of every Colour in

which

which it is held, but of a bright Blue when held in the Blue, and of a dull Red in the red Ray. Objects of any Colour will be successively of every Colour in which they are held, but more intensly of their own Colour.

Hence it appears, that an Object of any Colour reflects all manner of Rays, but more copiously those of that Colour, of which it is said to be: The Eye therefore being more affected with those Rays than the rest, which are more sparingly reflected, will perceive such an Object, as if it reflected only one sort of Rays.

7. A white Body reflects all sorts of Rays plentifully, and absorbs all sorts of Rays sparingly; but a black Body does just the reverse; therefore a black Body will be sooner heated in the Sun, and retain its Heat longer than a white one.

8. *The different Refrangibility of Rays is shewn by the following Experiment.*

Having by one Prism near the Hole of the Window of your dark Room, open'd a Sun-Beam into the colour'd *Spectrum* above mention'd: Behind a small Hole made in a Stand, which the *Spectrum* is to be thrown upon, fix a Prism in such manner, that if the red Rays fall thro' the Hole of the Stand, they will be refracted by that second Prism, and after that Refraction fall upon another Stand, still retaining their Colour. If the Violet Rays be thrown thro' the said Hole, they will after the Refraction thro' the second Prism fall unchang'd upon the second Stand making a Violet Spot, but much higher than the red Spot was; because the Violet being more refrangible than the Red, must be thrown higher by the second Prism, whose refracting Angle in that Case is downwards: The Orange will by the same means be thrown a lit-

tle

tle higher than the Red; the Yellow a little higher; the Green ſtill higher, and ſo of all the Colours in their Order. This is what Sir *Iſaac Newton* calls the *Experimentum Crucis* in his *Optics*, where he has given the whole Theory of *Light* and *Colours*; and the manner of making all the Experiments relating to it.

If a long piece of Paper about ſix Inches long, and half an Inch broad be divided into two Parts, by a Line Perpendicular to the long Sides of it, and one Half be painted Red, and the other Blue or Purple, the Paper ſeen thro' a Priſm will appear divided; the Red half appearing lower than the Blue half, or higher, according as you hold the refracting Angle of the Priſm upwards or downwards. But if inſtead of Painter's Colours the Red of one Priſm, and the Blue of another, be thrown upon the White Paper; the colour'd Parts of it ſeen thro' a third Priſm, will appear ſo much farther aſunder, as theſe Colours are more vivid and perfect than thoſe. If the Red from one Priſm and Violet from another be thrown upon the ſaid Paper, the Parts of the Paper will appear fartheſt from each other: If the Red from each Priſm be thrown upon the two Parts of the Paper, they will no way appear divided; but they will begin to ſeparate a little, if they receive one the Red, and the other the Orange; more, if the Yellow; and ſtill more if the Green, and ſo on, according to the Order of the Colours.

If the homogeneal Colours (which when all united make up White) are well ſeparated; how many Priſms ſoever they are made to paſs thro', however reflected, or however inflected they are, they never change their Colour or appear mix'd: and if they are thrown upon the Writing in a Book, the Lines will not appear crooked when look'd at thro'

a Prism, as it always happens when the white Light falls upon it, upon Account of the different Refrangibility of those Rays, of which the White is compounded.

9. That all other Lucid Bodies, as well as the Sun, emit Rays differently refrangible, was shewn by the Experiment of the Rays of the Candle; which entring obliquely into a bezell'd Looking-Glass Bar, are refracted, then fall upon the Quick-silver'd Surface, and after their Reflection from it, are refracted a second Time, as they come out of the oblique Surface of the said Bar: For then the homogeneal Rays (or the Rays that make each Colour) are so far separated from one another, that if the Violet Rays falls upon one Eye of any Person looking at the said Bar, the Red will fall upon the other Eye; if the Person looking be farther remov'd from the Bar, then one Eye will receive the Blue, whilst the other receives the Red, and so on; the Colours, or *Colour-making* Rays being farther asunder at a greater Distance from the Glass.

I have in the Philosophical Transactions, *Numb.* (348) *given a particular Account of these last Experiments, and easie Directions for making them; as also such of Sir* Isaac Newton'*s Experiments, as I made before the* Royal Society *by his Order; because some Gentlemen in* France *having tried them without Success, imagin'd the* Theory of Light and Colours *to be false. Each Circumstance is there mention'd and explain'd by proper Figures.*

10. That the Colours of the Rain-Bow, are only owing to the Refraction of the differently refrangible Rays, in their coming out of drops of falling Water, after one or more Reflections in the said Drops, appear'd by the Experiments made upon the hollow Glass Spheres fill'd with Water —— and by the Experiment

periment of the artificial Rain-Bow; when having the Sun behind, and a dark Place before, the Eye sees the Colours in the falling Drops of the spouted Water from the Fountain, plac'd between the Eye and the said dark Place.

Miscellaneous Experiments:

O*R such Experiments as are sometimes made in the Course, and sometimes not; because whatever they may serve to prove, is fully evinc'd from other Experiments, which are always made as set down in the Lectures. But these are generally perform'd the last Day, or after the Twenty Two above written Lectures* (which are so many Propositions depending upon each other) *are ended: Especially when the Auditors desire it.*

1. Muscular Motion is attempted to be explain'd by a Chain of Bladders raising a Weight, the Machine being so contriv'd, that a small Quantity of Air blown into a Chain of small Bladders, raises as great a Weight as a greater Quantity in the Chain of larger Bladders.

2. The compress'd Air weigh'd in the Copper Ball shews, that when the Density of the Air is doubled; its Weight is also doubled.

3. The Wind-gun throwing out a Bullet strongly, shews that the Spring of the Air is encreas'd in Proportion to its Compression; or when a great deal of it is crouded into a small Space.

 4. The

4. The Gage for difcovering how much Air is crouded into an opaque Veffel, (which confifts of a ftrong Glafs Tube with a fmall Bore, hermetically Seal'd at one end, and having the other end cover'd with the *Mercury* that is in the clofe Brafs Ciftern) helps to fhew, that the Denfity of the Air is as its Compreffion.

5. By a right Confideration of what Effects the Elafticity of Bodies muft produce, the Reafon appears why, in this fifth Experiment, when one fhort Ivory Cylinder ftrikes the firft of a row of other Ivory Cylinders that touch one another, it fhall only make the laft fly off; whether it ftrikes the firft with a great or fmall Velocity: But if two Cylinders are made to ftrike the Row, then the two laft Cylinders will be feparated; as alfo the Three laft, if the firft is ftruck by three Cylinders, *&c.* The fame is true of Ivory Balls, or Glafs Balls, or Object Glaffes of Telefcopes, if the Edges of them be not Convex.

6. The Force of the Steam of the heated Water, and the Centrifugal Force of a Body turning upon its Axis, together with the Reafon of the rifing of a Rocket into the Air; are fhewn by the Experiments on the Æolipile.

7. The Electrical Attraction of a Glafs Globe rubb'd with the Hand, whilft it is whirl'd round by a Wheel, is fhewn by the feveral Directions that it gives the Threads, when its *Effluvia* are excited: And that thefe *Effluvia* are luminous, and always fhoot themfelves where there is the leaft Refiftance, appears from the other Glafs Globe exhaufted of its Air, which gives a fine Purple Light within, when whirl'd round and rubb'd with the hand; an interrupted Light in Flafhes, when a little Air is let in; and all the Light outwardly, when the Air is wholly let into the Globe.

8. Two Glaſs Bubbles (of which one lies at top, and the other at the bottom of a Glaſs Jar half full of Water) are made to change Places by filling up the Jar with Water; which *Phænomenon*, tho' it appears ſtrange, is eaſily ſolv'd, when it is known, that the Water in the Jar was Salt, but that which was pour'd in warm and freſh; ſo the whole Medium or Fluid becoming ſpecifically lighter, is no longer able to ſuſtain the upper Bubble, which was hermetically Seal'd, when it had been made light enough to ſwim in very ſalt Water, tho' not in freſher; and the Water becoming warmer, expands the Air in the lower Bubble, whoſe Neck was open'd, and by that means part of the Water is driven out, and the Bubble becoming lighter, emerges.

9. This ninth Experiment is to confute Monſ. *Leibnitz*'s Notion, who in a Letter to the Abbot *Bignon* (printed in the Hiſtory of the *Royal Academy* at *Paris*) affirm'd, *That a Body does not weigh at all in a Fluid whilſt it is falling, but only when it is ſuſtain'd*; and endeavour'd to account for the Variation of the *Mercury* in the Barometer, by ſaying, *That the Clouds, as they fall in rainy Weather, eaſe the Air of all their Weight*, which is falſe; for it appears by this Experiment, that when the String that holds the Lead in the Tube of Water faſten'd to the Beam of the Balance is cut, the weight of the Water is encreas'd from the beginning of the fall of the Lead. *See a full Account of this in the* Philoſ. Tranſ. Numb. ( )

10. A Water-Clock, to ſhew, that the Surface of the Fluid in a Veſſel tapp'd at bottom, falls by a Motion uniformly diminiſh'd.

11. An Artificial *Vortex* in a Tin Bowl, to ſhew, that Planets ſpecifically lighter than the Parts of the Sun's Vortex (if there was one) wou'd

fall

fall into the Sun in a Spiral; and those that shou'd be denser wou'd fly off from the Sun in a Spiral. —And also to shew the difference between *absolute* and *relative* Motion.

12. Two Experiments to remove an Objection against the Motion of the Earth.

13. The *Linseed* Oil Thermometer measuring the heat of Boiling Water, and melted Metals.

14. A Thermometer rising by Heat (without Light) in *Vacuo*, almost as much as another in *Pleno*.

15. Models of Mechanical Engines for raising Water, or other uses.

A D-

ADDENDA.

What follows shou'd have begun the Sixth Lecture.

T*HE Third Law of Motion*, is this. Action and Re-action are always equal, and contrary in their Directions; that is, by Action and Re-action, equal Changes of Motion, are produc'd in Bodies.

Thus two Bodies attracting or repelling each other, will advance towards or recede from each other with equal Motions, tho' the Velocities will not be equal, unless the Bodies be so too. As a Stone falls to the Earth, the Earth rises up with the same Motion as the Stone falls; but the Earth being infinitely greater than the Stone, its Motion will produce a Velocity infinitely less, and therefore insensible. So a small Boat drawn by a Rope to a great Ship will seem to have all the Motion, the Ship being at rest; tho' the Ship has really as much Motion as the Boat, but that Motion distributed to all the Parts of the Ship can give the Ship but an insensible Velocity.

When a Cannon is fir'd in a great Ship, the force of the Powder does equally act against the Ball before it, and the Cannon behind, which wou'd recoil back with the same Motion as the Ball goes forward, if it was not fasten'd to the Ship; but instead of the Gun, the whole Ship recoils, which Motion in that Case amounts only to a shake of the Ship, upon account of the great quantity of Matter to be mov'd. The Air also re-acts against the Ball, but its Parts being easily separated upon account of its Fluidity, we are not so sensible of its Motion, unless the Ball passes very near us.

The

The Re-action of the Water against the Oars causes a Boat to move along —— that Re-action against the Hands and Feet, causes a Man to advance in swimming—— and by the Re-action of the Air Birds *swim in the Air*; that is, *do fly*.

As much as the Earth attracts the Moon, so much does the Moon attract the Earth, and all its Parts; but since the whole coheres and moves together, we are not sensible of this Motion, except on the Waters; which being Fluid, rise in Proportion, as their Tendency or Gravitation towards the Earth is diminish'd, as we shall shew, in explaining the *Phanomenon* of the Ebbing and Flowing of the Sea.

FINIS.